Electronic Supplementary Information (ESI)

CO_2 and Palladium Enabled Highly Chemoselective Hydroxylation of *gem*-Difluorocyclopropanes

Xingben Wang, Fang Xiao, and Frederic W. Patureau *

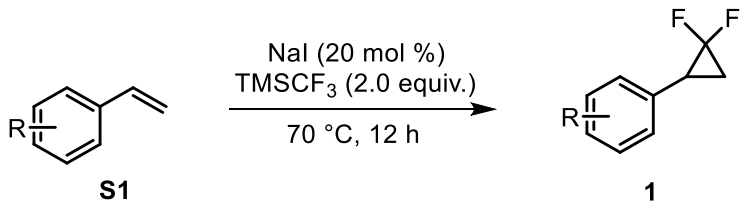
Institute of Organic Chemistry, RWTH Aachen University, Landoltweg 1, 52074 Aachen, Germany. E-mail: Frederic.Patureau@rwth-aachen.de

Table of Contents

1. General information

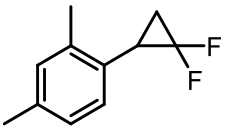
NMR spectra were obtained on an Agilent VNMRS 400 or a Bruker Av 600 using $CDCl_3$ as solvents. Chemical shifts are given in ppm and coupling constants (*J*) in Hz. ^1H NMR spectra were calibrated in relation to the reference measurement of TMS (0.00 ppm). ^{13}C NMR spectra were calibrated in relation to the deuterated solvent, namely $CDCl_3$ (77.16 ppm). For ^{19}F NMR, $CFCl_3$ presented a chemical shift at 0 ppm. The following abbreviations were used for ^1H NMR spectra to indicate the signal multiplicity: s (singlet), d (doublet), t (triplet), q (quartet), quint (quintet), sixt (sextet), sept (septet), and m (multiplet) as well as combinations of them. Flash chromatography was performed on silica gel (60 M, 0.04-0.063 mm) by standard technique. All the chemicals used for synthesis were purchased from Sigma Aldrich, abcr, Alfa Aesar, TCI, Fisher, or chemPUR. High-resolution mass spectra (HRMS) were recorded on a Thermo Scientific LTQ Orbitrap XL (ESI), Finnigan MAT95 (EI, 70 eV) or Bruker Maxis II LC-MS-System (APCI). IR spectra were measured on a PerkinElmer 100 FT-IR spectrometer with an UATR Diamond KRS-5 unit.

2. Preparation of some starting materials



S1 **1**

According to known procedures,[S1-S6] a schlenk-tube (50 mL) was charged with **S1** (10 mmol), NaI (2 mmol, 300 mg) and $TMSCF_3$ (20 mmol). The mixture was heated up to 70 °C. the reaction was stirred (12 h) while allowed to cool to room temperature. The reaction was quenched with water (20 mL), extracted with ethyl acetate (3x 10 mL), dried over $MgSO_4$ and concentrated under reduced pressure. The crude was purified by SiO_2 gel column chromatography to afford **1**.



1-(2,2-difluorocyclopropyl)-2,4-dimethylbenzene

1p: The crude mixture was purified by SiO_2 gel column chromatography with pentane. product was obtained by 85% isolated yield as colorless liquid.

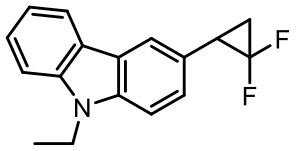
^{1}H NMR (600 MHz, Chloroform-*d*) δ 6.97 – 6.91 (m, 2H), 6.88 (d, *J* = 7.8 Hz, 1H), 2.56 (td, *J* = 12.5 Hz, *J* = 8.3 Hz, 1H), 2.25 (s, 3H), 2.21 (s, 3H), 1.72 – 1.64 (m, 1H), 1.51 – 1.44 (m, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -126.89 (dtd, *J* = 152.3, 13.0, 3.7 Hz), -141.15 (ddd, *J* = 152.3, 12.6, 4.7 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 138.4, 137.4, 130.9, 129.0, 127.8 (d, *J* = 5.2 Hz), 126.7, 113.3 (dd, *J* = 285.4, 282.4 Hz), 25.6 (t, *J* = 11.3 Hz), 21.1, 19.7, 16.0 (t, *J* = 10.6 Hz).

EI-HRMS: mass spectrometry: m/z calcd for $C_{11}H_{12}F_2$ $[M]^+$ 182.09071, measured 182.09012.

IR (neat, cm^{-1}): ṽ: 3007, 2924, 1617, 1507, 1462, 1376, 1305, 1226, 1194, 1090, 963, 819.



3-(2,2-difluorocyclopropyl)-9-ethyl-9*H*-carbazole

1y: The crude mixture was purified by SiO2 gel column chromatography with pentane. product was obtained by 45% isolated yield as colorless liquid.

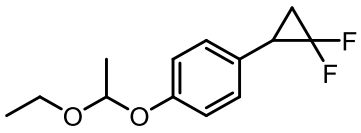
^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.13 – 8.09 (dt, *J* = 7.8 Hz, *J* = 0.8 Hz, 1H), 7.98 (s, 1H), 7.51 – 7.47 (m, 1H), 7.42 (d, *J* = 8.2 Hz, 1H), 7.38 (dd, *J* = 8.5 Hz, *J* = 0.6 Hz, 1H), 7.36 (dd, *J* = 8.5 Hz, *J* = 1.6 Hz, 1H), 7.26 – 7.22 (m, 1H), 4.37 (q, *J* = 7.3 Hz, 2H), 3.03 – 2.92 (m, 1H), 1.94 – 1.85 (m, 1H), 1.78 – 1.70 (m, 1H), 1.44 (t, *J* = 7.2 Hz, 3H).

^{19}F NMR (564 MHz, Chloroform-*d*) δ -125.96 (dtd, *J* = 152.5, 12.6, 3.6 Hz), -142.00 (ddd, *J* = 152.6, 12.8, 4.7 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 140.4, 139.3, 126.1, 126.0, 123.9, 123.2, 122.7, 120.6, 120.1, 119.0, 113.2 (t, *J* = 285.4 Hz), 108.7, 108.5, 37.7, 27.5 (t, *J* = 11.4 Hz), 17.3 (t, *J* = 10.5 Hz), 14.0.

EI-HRMS: mass spectrometry: m/z calcd for $C_{17}H_{15}NF_2$ $[M]^+$ 271.11726, measured 271.11648.

IR (neat, cm^{-1}): ṽ: 2977, 2891, 1768, 1602, 1491, 1379, 1324, 1231, 1153, 1042, 1018, 936.



1-(2,2-difluorocyclopropyl)-4-(1-ethoxyethoxy)benzene

1z: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 50:1). product was obtained by 86% isolated yield as colorless liquid (mixtures of diastereomers).

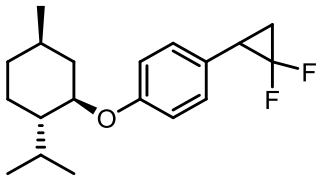
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.05 (d, *J* = 8.5 Hz, 2H), 6.91 – 6.85 (2nd order m, 2H), 5.28 (q, *J* = 5.3 Hz, 1H), 3.70 (dq, *J* = 9.3 Hz, *J* = 7.1 Hz, 1H), 3.46 (dq, *J* = 9.3 Hz, *J* = 7.1 Hz, 1H), 2.61 (td, *J* = 12.4 Hz, *J* = 8.2 Hz, 1H), 1.74 – 1.64 (m, 1H), 1.53 – 1.43 (m, 1H), 1.41 (d, *J* = 5.3 Hz, 3H), 1.12 (t, *J* = 7.1 Hz, 3H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -126.11 (dm, *J* = 153.6 Hz), -142.37 (dm, *J* = 153.6 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 156.3, 129.3, 127.0, 117.5, 112.8 (dd, *J* = 287.0, 283.4 Hz), 99.7, 99.7, 61.5, 26.7 (two dia. t, *J* = 11.9 Hz), 20.4, 17.1 (two dia. t, *J* = 10.6 Hz), 15.3.

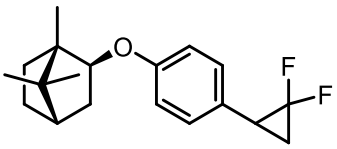
APCI-HRMS: mass spectrometry: m/z calcd for $C_{13}H_{15}O_2F_2$ $[M-H]^+$ 241.10346, measured 241.10403.

IR (neat, cm^{-1}): ṽ: 2983, 2934, 1738, 1613, 1513, 1468, 1380, 1302, 1233, 1184, 1121, 1076, 897.



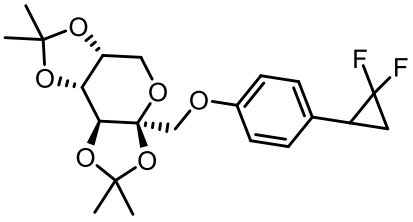
1-(2,2-difluorocyclopropyl)-4-(((1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl)oxy)benzene

1za (from DL-menthol): The crude mixture was purified by SiO_2 gel column chromatography with pentane. product was obtained by 45% isolated yield as colorless liquid (mixture of diastereomers).
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.14 (broad d, *J* = 8.6 Hz, 2H), 6.90 – 6.86 (2nd order m, 2H), 4.03 (td, *J* = 10.6 Hz, *J* = 4.1 Hz, 1H), 2.75 – 2.66 (m, 1H), 2.22 (sept.d, *J* = 6.8 Hz, *J* = 2.8 Hz, 1H), 2.16 (broad d, *J* = 12.5 Hz, 1H), 1.82 – 1.70 (m, 3H), 1.60 – 1.44 (m, 3H), 1.17 – 1.06 (m, 1H), 1.07 – 0.97 (m, 1H), 0.98 – 0.91 (m, 7H), 0.79 (d, *J* = 7.0 Hz, 3H).
^{19}F NMR (564 MHz, Chloroform-*d*) δ -126.10 (dm, *J* = 153.3 Hz), -142.33 (dm, *J* = 153.3 Hz).
^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.7, 129.3, 125.5, 115.9, 115.9, 115.0 – 110.8 (m, CF_2 groups, 2 dias), 77.7, 48.2, 40.4, 34.7, 31.6, 26.7 (t, *J* = 11.5 Hz), 26.2, 23.9, 22.3, 20.9, 17.1 (two dia. t, *J* = 10.5 Hz), 16.7.
EI-HRMS: mass spectrometry: m/z calcd for $C_{19}H_{26}OF_2$ $[M]^+$ 308.19517, measured 308.19460.
IR (neat, cm^{-1}): ṽ: 2925, 2868, 1613, 1512, 1465, 1375, 1297, 1238, 1187, 1096, 1043, 1015.



(1*S*,2*S*,4*S*)-2-(4-(2,2-difluorocyclopropyl)phenoxy)-1,7,7-trimethylbicyclo[2.2.1]heptane

1zb (from DL-isoborneol): the crude mixture was purified by SiO_2 gel column chromatography with pentane. product was obtained by 55% isolated yield as colorless liquid (mixture of diastereomers).
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.17 – 7.11 (2nd order m, 2H), 6.86 – 6.81 (2nd order m, 2H), 4.36 – 4.30 (m, 1H), 2.76 – 2.67 (m, 1H), 2.42 – 2.35 (m, 1H), 2.29 – 2.24 (m, 1H), 1.83 – 1.75 (m, 3H), 1.59 – 1.52 (m, 1H), 1.40 – 1.34 (m, 1H), 1.31 – 1.26 (m, 1H), 1.15 – 1.11 (m, 1H), 0.97 (s, 3H), 0.95 (s, 3H), 0.94 (s, 3H).
^{19}F NMR (564 MHz, Chloroform-*d*) δ -126.16 (dm, *J* = 153.2 Hz), -142.30 (dm, *J* = 153.1 Hz).
^{13}C NMR (151 MHz, Chloroform-*d*) δ 158.5, 158.5, 129.2, 125.1, 115.5, 112.9 (dd, *J* = 286.7, 283.7 Hz), 83.0 (d, *J* = 2.8 Hz, or two dia. s), 49.6, 47.7, 45.3, 37.0, 28.1, 26.9, 26.6 (t, *J* = 11.4 Hz), 19.9, 19.1, 17.1 (two dia. t, *J* = 10.5 Hz), 13.9.
APCI-HRMS: mass spectrometry: m/z calcd for $C_{19}H_{23}OF_2$ $[M-H]^+$ 305.17115, measured 305.17160.
IR (neat, cm^{-1}): ṽ: 3362, 2950, 2878, 1613, 1513, 1468, 1372, 1243, 1186, 1113, 1047, 933.



(3a*S*,5a*R*,8a*R*,8b*S*)-3a-((4-(2,2-difluorocyclopropyl)phenoxy)methyl)-2,2,7,7-tetramethyltetrahydro-5*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran

1zc (from a fructopyranose derivative): The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 30:1). product was obtained by 60% isolated yield as colorless liquid (mixture of diastereomers).

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.07 (d, *J* = 8.4 Hz, 2H), 6.82 (broad d, *J* = 8.7 Hz, 2H), 4.57 (dd, *J* = 7.9, 2.6 Hz, 1H), 4.47 (d, *J* = 2.6 Hz, 1H), 4.19 (dd, *J* = 8.0, 1.7 Hz, 1H), 4.07 (d, *J* = 10.1 Hz, 1H), 3.95 (d, *J* = 10.1 Hz, 1H), 3.90 (dd, *J* = 13.0, 1.9 Hz, 1H), 3.72 (d, *J* = 13.0 Hz, 1H), 2.66 – 2.59 (m, 1H), 1.74 – 1.66 (m, 1H), 1.51 – 1.44 (m, 4H), 1.41 (s, 6H), 1.27 (s, 3H).

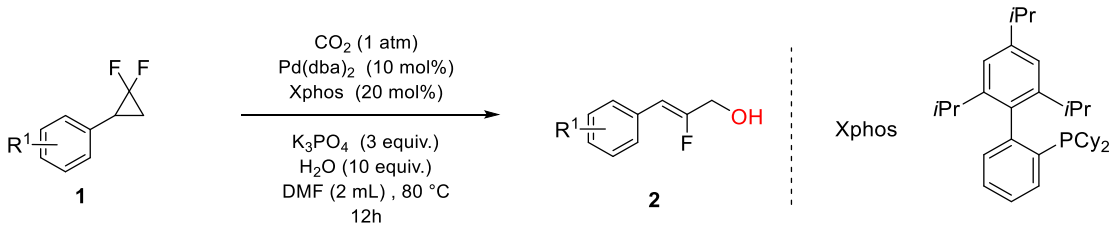
^{19}F NMR (565 MHz, Chloroform-*d*) δ -126.25 (dm, *J* = 153.4 Hz), -142.36 (dm, *J* = 153.5 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.9, 129.3, 126.3, 114.8, 112.8 (dd, *J* = 286.7, 283.7 Hz), 109.2, 109.1, 102.3, 71.1, 70.3, 70.1, 69.0, 69.0, 61.3, 26.7, 26.6 (t, *J* = 11.2 Hz), 26.1, 25.5, 24.2, 17.1 (two dia. t, *J* = 10.5 Hz).

ESI-HRMS: mass spectrometry: m/z calcd for $C_{21}H_{26}O_6F_2Na$ $[M+Na]^+$ 435.15897, measured 435.15953.

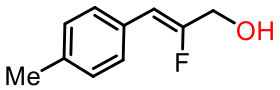
IR (neat, cm^{-1}): ṽ: 3359, 2989, 2933, 1733, 1616, 1515, 1462, 1378, 1298, 1247, 1100, 1059, 932.

3. General procedure for product 2



XPhos (19.1 mg, 0.04 mmol) and $Pd(dba)_2$ (11.4 mg, 0.02 mmol), *gem*-difluorocyclopropanes **1** (0.2 mmol), H_2O (10.0 equiv., 36 mg), K_3PO_4 (3.0 equiv., 127.2 mg) were dissolved in 2 mL DMF and CO_2 was bubbled through the solution for about two minutes. Then, the mixture was sealed under CO_2 (1atm) and stirred at 80 °C for about 12h, until the starting material was consumed (monitored by TLC). Then, the mixture was filtered through celite and the filtrate was concentrated to dryness. The crude was purified by column chromatography to give the products **2**.

4. Product characterization



(*Z*)-2-fluoro-3-(*p*-tolyl)prop-2-en-1-ol

2a: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 31 mg product was obtained by 93% isolated yield as yellow liquid.

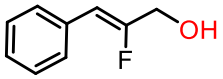
^{1}H NMR (600 MHz, Chloroform-d) δ 7.41 (d, *J* = 8.2 Hz, 2H), 7.15 (d, *J* = 8.0 Hz, 2H), 5.75 (d, *J* = 38.9 Hz, 1H), 4.27 (d, *J* = 14.8 Hz, 2H), 2.35 (s, 3H), 1.96 (s, 1H).

^{19}F NMR (565 MHz, Chloroform-d) δ -114.35 (dt, *J* = 38.8, 14.9 Hz).

^{13}C NMR (151 MHz, Chloroform-d) δ 157.7 (d, *J* = 265.4 Hz), 137.5 (d, *J* = 2.4 Hz), 129.9 (d, *J* = 2.6 Hz), 129.3, 128.8 (d, *J* = 7.2 Hz), 107.7 (d, *J* = 6.8 Hz), 62.2 (d, *J* = 32.2 Hz), 21.4.

EI-HRMS: mass spectrometry: m/z calcd for $C_{10}H_{11}OF$ $[M]^+$ 166.07939, measured 166.07877.

IR (neat, cm^{-1}): ṽ: 3313, 2920, 2856, 1916, 1690, 1511, 1445, 1341, 1220, 1157, 1072, 865, 696.



(*Z*)-2-fluoro-3-phenylprop-2-en-1-ol

2b: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 25 mg product was obtained by 82% isolated yield as yellow liquid.

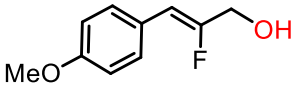
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.43 (d, *J* = 6.9 Hz, 2H), 7.27 (t, *J* = 7.7 Hz, 2H), 7.18 (t, *J* = 7.0 Hz, 1H), 5.71 (d, *J* = 38.7 Hz, 1H), 4.21 (d, *J* = 14.3 Hz, 2H), 1.78 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -113.42 (dt, *J* = 38.3, 14.1 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 158.3 (d, *J* = 266.8 Hz), 132.8 (d, *J* = 3.6 Hz), 128.9 (d, *J* = 7.3 Hz), 128.7, 127.7 (d, *J* = 2.6 Hz), 107.7 (d, *J* = 6.8 Hz), 62.1 (d, *J* = 32.9 Hz).

EI-HRMS: mass spectrometry: m/z calcd for C_9H_9OF $[M]^+$ 152.06374, measured 152.06316.

IR (neat, cm^{-1}): ṽ: 3310, 2922, 2854, 2085, 1663, 1536, 1455, 1346, 1281, 1160, 1074, 974, 752.



(*Z*)-2-fluoro-3-(4-methoxyphenyl)prop-2-en-1-ol

2c: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 33 mg product was obtained by 91% isolated yield as yellow solid.

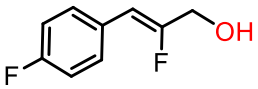
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.45 (d, *J* = 8.7 Hz, 2H), 6.87 (d, *J* = 8.7 Hz, 2H), 5.72 (d, *J* = 38.9 Hz, 1H), 4.27 (d, *J* = 15.4 Hz, 2H), 3.81 (s, 3H), 1.85 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -116.18 (dt, *J* = 39.0, 15.3 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 159.0 (d, *J* = 2.9 Hz), 157.0 (d, *J* = 264.1 Hz), 130.2 (d, *J* = 7.3 Hz), 125.5 (d, *J* = 2.9 Hz), 114.1, 107.4 (d, *J* = 7.2 Hz), 62.2 (d, *J* = 32.1 Hz), 55.4.

EI-HRMS: mass spectrometry: m/z calcd for $C_{10}H_{11}O_2F$ $[M]^+$ 182.07431, measured 182.07370.

IR (neat, cm^{-1}): ṽ: 3369, 2928, 2850, 1899, 1695, 1606, 1509, 1345, 1297, 1159, 1009, 859, 695.



(*Z*)-2-fluoro-3-(4-fluorophenyl)prop-2-en-1-ol

2d: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 25 mg product was obtained by 73% isolated yield as yellow solid.

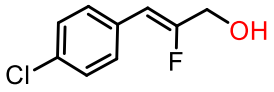
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.51 – 7.45 (m, 2H), 7.02 (t, *J* = 8.7 Hz, 2H), 5.75 (d, *J* = 38.4 Hz, 1H), 4.28 (d, *J* = 14.4 Hz, 2H), 1.92 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -113.68 – -113.77 (m), -114.55 (dt, *J* = 38.6, 14.3 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 162.1 (dd, *J* = 247.6, 3.1 Hz), 158.0 (dd, *J* = 265.9, 2.4 Hz), 130.5 (t, *J* = 7.8 Hz), 128.9 (t, *J* = 3.0 Hz), 115.6 (d, *J* = 21.7 Hz), 106.6 (d, *J* = 6.8 Hz), 62.0 (d, *J* = 32.7 Hz).

EI-HRMS: mass spectrometry: m/z calcd for $C_9H_8OF_2$ $[M]^+$ 170.05432, measured 170.05381.

IR (neat, cm^{-1}): ṽ: 3355, 2922, 2853, 1908, 1691, 1602, 1506, 1342, 1236, 1159, 1013, 861, 782.



(Z)-3-(4-chlorophenyl)-2-fluoroprop-2-en-1-ol

2e: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 10 mg product was obtained by 27% isolated yield as yellow solid.

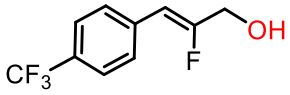
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.41 (d, *J* = 8.6 Hz, 2H), 7.28 (d, *J* = 8.6 Hz, 2H), 5.73 (d, *J* = 38.2 Hz, 1H), 4.25 (d, *J* = 13.7 Hz, 2H), 1.87 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -112.51 (dt, *J* = 38.3, 13.4 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 158.7 (d, *J* = 267.5 Hz), 133.3 (d, *J* = 3.4 Hz), 131.3 (d, *J* = 2.5 Hz), 130.1 (d, *J* = 7.6 Hz), 128.8, 106.5 (d, *J* = 6.5 Hz), 61.9 (d, *J* = 32.7 Hz).

EI-HRMS: mass spectrometry: m/z calcd for C_9H_8OClF $[M]^+$ 186.02477, measured 186.02418.

IR (neat, cm^{-1}): ṽ: 3406, 2921, 2854, 1687, 1591, 1489, 1407, 1339, 1204, 1159, 1089, 1018, 865.



(*Z*)-2-fluoro-3-(4-(trifluoromethyl)phenyl)prop-2-en-1-ol

2f: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 31 mg product was obtained by 70% isolated yield as yellow liquid.

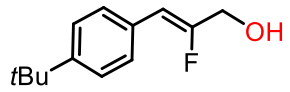
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.64 – 7.55 (m, 4H), 5.85 (d, *J* = 38.1 Hz, 1H), 4.32 (d, *J* = 12.7 Hz, 2H), 1.94 (broad s, 1H).

^{19}F NMR (564 MHz, Chloroform-*d*) δ -62.67 (broad s), -110.29 (dt, *J* = 38.1, 12.7 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 160.0 (d, *J* = 269.7 Hz), 136.4, 129.4 (qd, *J* = 32.3, 2.3 Hz), 128.9 (d, *J* = 7.6 Hz), 125.6 (q, *J* = 3.9 Hz), 124.2 (q, *J* = 271.9 Hz), 106.2 (d, *J* = 6.1 Hz), 61.7 (d, *J* = 33.3 Hz).

EI-HRMS: mass spectrometry: m/z calcd for $C_{10}H_8OF_4$ $[M]^+$ 220.05113, measured 220.05093.

IR (neat, cm^{-1}): ṽ: 3286, 2927, 2860, 1693, 1617, 1449, 1413, 1321, 1168, 1066, 1017, 864.



(Z)-3-(4-(tert-butyl)phenyl)-2-fluoroprop-2-en-1-ol

2g: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 33 mg product was obtained by 79% isolated yield as yellow liquid.

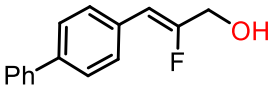
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.46 (d, *J* = 8.4 Hz, 2H), 7.37 (d, *J* = 8.5 Hz, 2H), 5.77 (d, *J* = 38.9 Hz, 1H), 4.28 (d, *J* = 14.4 Hz, 2H), 1.94 (broad s, 1H), 1.33 (s, 9H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -114.32 (dt, *J* = 39.0, 14.8 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.9 (d, *J* = 265.7 Hz), 150.7 (d, *J* = 2.2 Hz), 130.0 (d, *J* = 2.8 Hz), 128.6 (d, *J* = 7.1 Hz), 125.6, 107.5 (d, *J* = 6.8 Hz), 62.1 (d, *J* = 32.5 Hz), 34.7, 31.4.

EI-HRMS: mass spectrometry: m/z calcd for $C_{13}H_{17}OF$ $[M]^+$ 208.12634, measured 208.12620.

IR (neat, cm^{-1}): ṽ: 3344, 2961, 2869, 1695, 1512, 1462, 1364, 1270, 1159, 1072, 1022, 866, 671.



(*Z*)-3-([1,1'-biphenyl]-4-yl)-2-fluoroprop-2-en-1-ol

2h: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 41 mg product was obtained by 90% isolated yield as yellow solid.

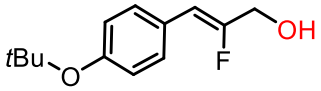
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.64 – 7.57 (m, 6H), 7.45 (t, *J* = 7.8 Hz, 2H), 7.35 (t, *J* = 7.4 Hz, 1H), 5.84 (d, *J* = 38.7 Hz, 1H), 4.32 (d, *J* = 14.2 Hz, 2H), 1.88 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -112.92 (dt, *J* = 38.8, 14.4 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 158.5 (d, *J* = 267.0 Hz), 140.7, 140.3 (d, *J* = 2.5 Hz), 131.9 (d, *J* = 2.6 Hz), 129.3 (d, *J* = 7.2 Hz), 128.9, 127.5, 127.3, 127.1, 107.3 (d, *J* = 6.6 Hz), 62.1 (d, *J* = 32.7 Hz).

EI-HRMS: mass spectrometry: m/z calcd for $C_{15}H_{13}OF$ $[M]^+$ 228.09504, measured 228.09430.

IR (neat, cm^{-1}): ṽ: 3308, 2923, 2854, 2094, 1682, 1633, 1480, 1335, 1161, 1027, 968, 757.



(*Z*)-3-(4-(*tert*-butoxy)phenyl)-2-fluoroprop-2-en-1-ol

2i: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 43 mg product was obtained by 96% isolated yield as yellow liquid.

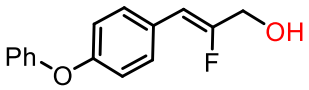
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.41 (d, *J* = 8.2 Hz, 2H), 6.96 (d, *J* = 8.2 Hz, 2H), 5.72 (d, *J* = 38.8 Hz, 1H), 4.26 (d, *J* = 14.9 Hz, 2H), 1.90 (broad s, 1H), 1.35 (s, 9H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -115.16 (dt, *J* = 39.0, 15.0 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.5 (d, *J* = 265.1 Hz), 154.9 (d, *J* = 3.0 Hz), 129.5 (d, *J* = 7.3 Hz), 128.0 (d, *J* = 2.9 Hz), 124.2, 107.3 (d, *J* = 7.1 Hz), 79.0, 62.1 (d, *J* = 32.5 Hz), 29.0.

EI-HRMS: mass spectrometry: m/z calcd for $C_{13}H_{17}O_2F$ $[M]^+$ 224.12126, measured 224.12078.

IR (neat, cm^{-1}): ṽ: 3378, 2976, 2860, 1604, 1569, 1505, 1390, 1366, 1241, 1157, 1021, 890.



(*Z*)-2-fluoro-3-(4-phenoxyphenyl)prop-2-en-1-ol

2j: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 42 mg product was obtained by 86% isolated yield as yellow liquid.

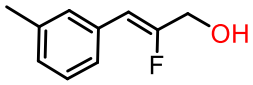
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.51 – 7.46 (2^{nd} order m, 2H), 7.38 – 7.32 (2^{nd} order m, 2H), 7.12 (tt, *J* = 7.3 Hz, *J* = 2.3 Hz, 1H), 7.05 – 7.01 (2^{nd} order m, 2H), 6.99 – 6.96 (2^{nd} order m, 2H), 5.76 (d, *J* = 38.6 Hz, 1H), 4.28 (d, *J* = 14.7 Hz, 2H), 1.90 (broad s, 1H).

^{19}F NMR (564 MHz, Chloroform-*d*) δ -114.94 (dt, *J* = 38.6, 14.8 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.6 (d, *J* = 265.4 Hz), 157.0, 156.8 (d, *J* = 3.1 Hz), 130.3 (d, *J* = 7.4 Hz), 129.9, 127.9 (d, *J* = 2.9 Hz), 123.6, 119.3, 118.8, 107.1 (d, *J* = 7.2 Hz), 62.1 (d, *J* = 32.4 Hz).

EI-HRMS: mass spectrometry: m/z calcd for $C_{15}H_{13}O_2F$ $[M]^+$ 244.08996 measured 224.08931.

IR (neat, cm^{-1}): ṽ: 3357, 2921, 2853, 1692, 1633, 1589, 1419, 1342, 1284, 1158, 1070, 864, 693.



(*Z*)-2-fluoro-3-(*m*-tolyl)prop-2-en-1-ol

2k: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 30 mg product was obtained by 90% isolated yield as yellow liquid.

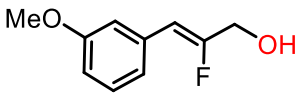
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.25 – 7.22 (m, 2H), 7.18 – 7.13 (m, 1H), 7.00 (d, *J* = 7.6 Hz, 1H), 5.67 (d, *J* = 38.8 Hz, 1H), 4.19 (d, *J* = 14.5 Hz, 2H), 2.27 (s, 3H), 1.88 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -113.47 (dt, *J* = 38.5, 14.2 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 158.1 (d, *J* = 266.4 Hz), 138.2, 132.7 (d, *J* = 3.1 Hz), 129.5 (d, *J* = 7.3 Hz), 128.5, 128.5 (d, *J* = 2.8 Hz), 126.0 (d, *J* = 7.7 Hz), 107.7 (d, *J* = 6.8 Hz), 62.1 (d, *J* = 32.7 Hz), 21.6.

EI-HRMS: mass spectrometry: m/z calcd for $C_{10}H_{11}OF$ $[M]^+$ 166.07939, measured 166.07884.

IR (neat, cm^{-1}): ṽ: 3307, 2922, 2853, 2161, 1662, 1547, 1461, 1276, 1159, 1076, 855, 696.



(*Z*)-2-fluoro-3-(3-methoxyphenyl)prop-2-en-1-ol

2l: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 34 mg product was obtained by 93% isolated yield as yellow liquid.

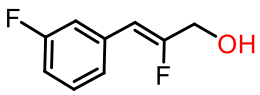
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.27 (t, *J* = 7.9 Hz, 1H), 7.13 – 7.08 (m, 2H), 6.84 (ddd, *J* = 8.2 Hz, *J* = 2.5 Hz, *J* = 1.0 Hz, 1H), 5.78 (d, *J* = 38.4 Hz, 1H), 4.30 (d, *J* = 14.2 Hz, 2H), 3.83 (s, 3H), 1.90 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -112.64 (dt, *J* = 38.3, 14.1 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) 159.7, 158.47 (d, *J* = 267.1 Hz), 134.1 (d, *J* = 2.6 Hz), 129.6, 121.5 (d, *J* = 6.7 Hz), 114.2 (d, *J* = 7.6 Hz), 113.5 (d, *J* = 2.2 Hz), 107.5 (d, *J* = 6.5 Hz), 62.0 (d, *J* = 32.7 Hz), 55.4.

EI-HRMS: mass spectrometry: m/z calcd for $C_{10}H_{11}O_2F$ $[M]^+$ 182.07431, measured 182.07373.

IR (neat, cm^{-1}): ṽ: 3371, 2928, 2855, 2086, 1694, 1581, 1458, 1294, 1161, 1041, 866, 778.



(*Z*)-2-fluoro-3-(3-fluorophenyl)prop-2-en-1-ol

2m: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 28 mg product was obtained by 82% isolated yield as yellow liquid.

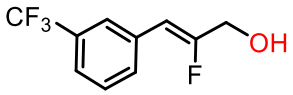
^{1}H NMR (600 MHz, Chloroform-d) δ 7.24 – 7.13 (m, 3H), 6.88 (tdd, *J* = 8.4 Hz, *J* = 2.6 Hz, *J* = 1.0 Hz, 1H), 5.71 (d, *J* = 37.9 Hz, 1H), 4.22 (d, *J* = 13.4 Hz, 2H), 1.81 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-d) δ -111.41 (dt, *J* = 38.0, 13.4 Hz), -113.17 – -113.26 (m).

^{13}C NMR (151 MHz, Chloroform-d) δ 163.01 (d, *J* = 244.7 Hz), 159.2 (d, *J* = 268.3 Hz), 134.9 (dd, *J* = 8.4, 2.5 Hz), 130.0 (d, *J* = 8.5 Hz), 124.6 (dd, *J* = 6.5, 2.9 Hz), 115.5 (dd, *J* = 22.5, 8.4 Hz), 114.6 (dd, *J* = 21.3, 2.2 Hz), 106.6 (dd, *J* = 6.3, 2.7 Hz), 61.8 (d, *J* = 33.2 Hz).

EI-HRMS: mass spectrometry: m/z calcd for $C_9H_8OF_2$ $[M]^+$ 170.05432, measured 170.05404.

IR (neat, cm^{-1}): ṽ: 3348, 2927, 2861, 1694, 1583, 1486, 1344, 1252, 1158, 1026, 951, 877, 782.



(*Z*)-2-fluoro-3-(3-(trifluoromethyl)phenyl)prop-2-en-1-ol

2n: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 36 mg product was obtained by 82% isolated yield as yellow liquid.

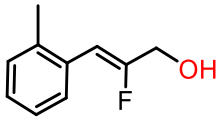
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.75 (s, 1H), 7.68 (d, *J* = 7.7 Hz, 1H), 7.51 (d, *J* = 7.8 Hz, 1H), 7.46 (t, *J* = 7.7 Hz, 1H), 5.85 (d, *J* = 37.9 Hz, 1H), 4.32 (d, *J* = 13.0 Hz, 2H), 1.85 (broad s, 1H).

^{19}F NMR (564 MHz, Chloroform-*d*) δ -62.85 (broad s), -111.15 (dt, *J* = 38.0, 13.1 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 159.6 (d, *J* = 268.8 Hz), 133.6 (d, *J* = 2.8 Hz), 131.9 (d, *J* = 7.1 Hz), 131.1 (q, *J* = 32.4 Hz), 129.1, 125.6 – 125.3 (m), 124.2 (q, *J* = 272.5 Hz), 124.3 – 124.1 (m), 106.2 (d, *J* = 6.1 Hz), 61.7 (d, *J* = 33.0 Hz).

EI-HRMS: mass spectrometry: m/z calcd for $C_{10}H_8OF_4$ $[M]^+$ 220.05113, measured 220.05057.

IR (neat, cm^{-1}): ṽ: 3379, 2930, 2858, 1697, 1447, 1327, 1163, 1124, 1037, 904, 798, 697.



(*Z*)-2-fluoro-3-(*o*-tolyl)prop-2-en-1-ol

2o: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 25 mg product was obtained by 75% isolated yield as yellow liquid.

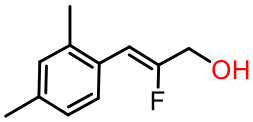
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.65 (d, *J* = 7.3 Hz, 1H), 7.22 – 7.14 (m, 3H), 5.93 (d, *J* = 37.9 Hz, 1H), 4.32 (d, *J* = 14.0 Hz, 2H), 2.32 (s, 3H), 1.82 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -115.47 (dt, *J* = 38.0, 14.0 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 158.1 (d, *J* = 265.5 Hz), 136.0, 131.3 (d, *J* = 1.9 Hz), 130.2, 129.4 (d, *J* = 9.5 Hz), 127.7, 126.1, 105.0 (d, *J* = 7.8 Hz), 62.1 (d, *J* = 33.2 Hz), 20.3.

EI-HRMS: mass spectrometry: m/z calcd for $C_{10}H_{11}OF$ $[M]^+$ 166.07939, measured 166.07916.

IR (neat, cm^{-1}): ṽ: 3355, 2925, 2862, 1692, 1454, 1383, 1198, 1161, 1070, 1025, 876, 752.



(*Z*)-3-(2,4-dimethylphenyl)-2-fluoroprop-2-en-1-ol

2p: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 32 mg product was obtained by 89% isolated yield as yellow liquid.

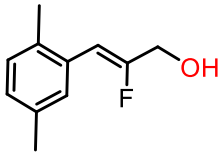
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.56 (d, *J* = 7.7 Hz, 1H), 7.05 – 6.97 (m, 2H), 5.89 (d, *J* = 38.0 Hz, 1H), 4.30 (d, *J* = 14.5 Hz, 2H), 2.31 (s, 3H), 2.29 (s, 3H), 1.87 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -116.08 (dt, *J* = 38.1, 14.4 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.7 (d, *J* = 264.7 Hz), 137.5 (d, *J* = 1.1 Hz), 135.9, 131.0, 129.3 (d, *J* = 9.7 Hz), 128.3 (d, *J* = 2.3 Hz), 126.8, 105.0 (d, *J* = 7.7 Hz), 62.2 (d, *J* = 32.8 Hz), 21.3, 20.2.

EI-HRMS: mass spectrometry: m/z calcd for $C_{11}H_{13}OF$ $[M]^+$ 180.09504, measured 180.09453.

IR (neat, cm^{-1}): ṽ: 3358, 2923, 2860, 1691, 1614, 1499, 1448, 1343, 1219, 1165, 1071, 1024, 854.



(*Z*)-3-(2,5-dimethylphenyl)-2-fluoroprop-2-en-1-ol

2q: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 25 mg product was obtained by 69% isolated yield as yellow liquid.

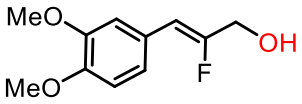
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.47 (s, 1H), 7.07 (d, *J* = 7.7 Hz, 1H), 6.99 (broad d, *J* = 7.4 Hz, 1H), 5.90 (d, *J* = 38.0 Hz, 1H), 4.31 (d, *J* = 14.2 Hz, 2H), 2.32 (s, 3H), 2.28 (s, 3H), 1.88 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -115.60 (dt, *J* = 38.1, 14.1 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.9 (d, *J* = 265.3 Hz), 135.4, 132.9, 131.0 (d, *J* = 1.9 Hz), 130.1, 130.0 (d, *J* = 9.5 Hz), 128.5 (d, *J* = 0.9 Hz), 105.2 (d, *J* = 7.7 Hz), 62.2 (d, *J* = 33.2 Hz), 21.2, 19.8.

EI-HRMS: mass spectrometry: m/z calcd for $C_{11}H_{13}OF$ $[M]^+$ 180.09504, measured 180.09482.

IR (neat, cm^{-1}): ṽ: 3347, 2924, 2863, 1692, 1613, 1497, 1451, 1345, 1282, 1166, 1071, 1026, 873.



(*Z*)-3-(3,4-dimethoxyphenyl)-2-fluoroprop-2-en-1-ol

2r: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 33 mg product was obtained by 78% isolated yield as yellow liquid.

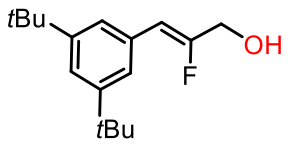
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.13 (d, *J* = 2.0 Hz, 1H), 7.02 (dd, *J* = 8.3, 1.9 Hz, 1H), 6.83 (d, *J* = 8.3 Hz, 1H), 5.71 (d, *J* = 38.6 Hz, 1H), 4.27 (d, *J* = 15.2 Hz, 2H), 3.88 (s, 6H), 1.99 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -115.78 (dt, *J* = 38.8, 15.4 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.1 (d, *J* = 264.2 Hz), 148.9, 148.7 (d, *J* = 2.6 Hz), 125.8 (d, *J* = 2.9 Hz), 121.9 (d, *J* = 6.3 Hz), 111.8 (d, *J* = 8.7 Hz), 111.1, 107.6 (d, *J* = 6.7 Hz), 62.2 (d, *J* = 32.2 Hz), 56.0, 55.9.

EI-HRMS: mass spectrometry: m/z calcd for $C_{11}H_{13}O_3F$ $[M]^+$ 212.08487, measured 212.08423.

IR (neat, cm^{-1}): ṽ: 3461, 2927, 2843, 1689, 1602, 1513, 1416, 1263, 1148, 1022, 866, 766.



(*Z*)-3-(3,5-di-*tert*-butylphenyl)-2-fluoroprop-2-en-1-ol

2s: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 40 mg product was obtained by 76% isolated yield as yellow liquid.

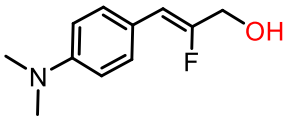
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.38 (d, *J* = 1.8 Hz, 2H), 7.35 (t, *J* = 1.8 Hz, 1H), 5.81 (d, *J* = 38.8 Hz, 1H), 4.29 (d, *J* = 14.8 Hz, 2H), 1.89 (broad s, 1H), 1.34 (s, 18H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -114.29 (dt, *J* = 39.0, 15.0 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.7 (d, *J* = 265.7 Hz), 151.0, 131.9 (d, *J* = 3.0 Hz), 123.2 (d, *J* = 7.2 Hz), 121.9 (d, *J* = 2.2 Hz), 108.6 (d, *J* = 6.6 Hz), 62.3 (d, *J* = 32.3 Hz), 35.0, 31.6.

EI-HRMS: mass spectrometry: m/z calcd for $C_{17}H_{25}OF$ $[M]^+$ 264.18894, measured 264.18828.

IR (neat, cm^{-1}): ṽ: 3350, 2958, 2867, 2156, 1692, 1694, 1461, 1362, 1248, 1162, 1072, 1024, 863.



(*Z*)-3-(4-(dimethylamino)phenyl)-2-fluoroprop-2-en-1-ol

2t: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 32 mg product was obtained by 82% isolated yield as yellow solid.

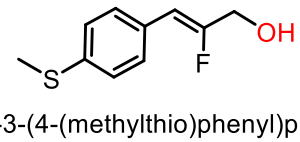
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.41 (d, *J* = 8.8 Hz, 2H), 6.69 (d, *J* = 8.8 Hz, 2H), 5.66 (d, *J* = 39.4 Hz, 1H), 4.25 (d, *J* = 16.4 Hz, 2H), 2.97 (s, 6H), 1.91 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -117.94 (dt, *J* = 39.2, 16.3 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 155.9 (d, *J* = 261.8 Hz), 149.9 (d, *J* = 2.4 Hz), 129.9 (d, *J* = 7.2 Hz), 121.1 (d, *J* = 1.8 Hz), 112.4, 108.1 (d, *J* = 7.4 Hz), 62.5 (d, *J* = 31.6 Hz), 40.5.

EI-HRMS: mass spectrometry: m/z calcd for $C_{11}H_{14}ONF$ $[M]^+$ 195.10594, measured 195.10523.

IR (neat, cm^{-1}): ṽ: 3382, 2920, 2853, 1690, 1607, 1522, 1441, 1355, 1230, 1197, 1156, 1067, 1008.



(*Z*)-2-fluoro-3-(4-(methylthio)phenyl)prop-2-en-1-ol

2u: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 32 mg product was obtained by 81% isolated yield as yellow solid.

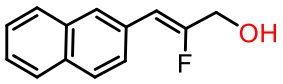
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.43 (d, *J* = 8.5 Hz, 2H), 7.21 (d, *J* = 8.5 Hz, 2H), 5.73 (d, *J* = 38.7 Hz, 1H), 4.27 (d, *J* = 14.5 Hz, 2H), 2.49 (s, 3H), 1.92 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -113.38 (dt, *J* = 38.6, 14.4 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 158.1 (d, *J* = 266.4 Hz), 138.0 (d, *J* = 2.8 Hz), 129.6 (d, *J* = 3.0 Hz), 129.2 (d, *J* = 7.3 Hz), 126.5, 107.2 (d, *J* = 6.8 Hz), 62.1 (d, *J* = 32.6 Hz), 15.8.

EI-HRMS: mass spectrometry: m/z calcd for $C_{10}H_{11}OFS$ $[M]^+$ 198.05146, measured 198.05086.

IR (neat, cm^{-1}): ṽ: 3365, 2920, 2854, 1690, 1593, 1492, 1408, 1345, 1208, 1159, 1095, 1006, 866.



(*Z*)-2-fluoro-3-(naphthalen-2-yl)prop-2-en-1-ol

2v: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 31 mg product was obtained by 77% isolated yield as yellow solid.

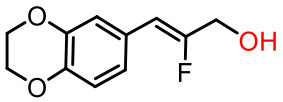
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.93 (s, 1H), 7.85 – 7.78 (m, 3H), 7.68 (dd, *J* = 8.5 Hz, *J* = 1.7 Hz, 1H), 7.50 – 7.44 (m, 2H), 5.94 (d, *J* = 38.7 Hz, 1H), 4.34 (d, *J* = 14.2 Hz, 2H), 1.98 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -112.93 (dt, *J* = 39.0, 14.2 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 158.4 (d, *J* = 267.0 Hz), 133.4, 132.6 (d, *J* = 2.0 Hz), 130.3 (d, *J* = 3.1 Hz), 128.1, 128.1, 127.9 (d, *J* = 7.4 Hz), 127.6, 126.5 (d, *J* = 7.7 Hz), 126.2, 126.1, 107.7 (d, *J* = 6.7 Hz), 62.0 (d, *J* = 32.7 Hz).

EI-HRMS: mass spectrometry: m/z calcd for $C_{13}H_{11}OF$ $[M]^+$ 202.07939, measured 202.07884.

IR (neat, cm^{-1}): ṽ: 3311, 2922, 3854, 1687, 1503, 1458, 1355, 1279, 1160, 1015, 952, 831.



(*Z*)-3-(2,3-dihydrobenzo[*b*][1,4]dioxin-6-yl)-2-fluoroprop-2-en-1-ol

2w: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 35 mg product was obtained by 83% isolated yield as yellow liquid.

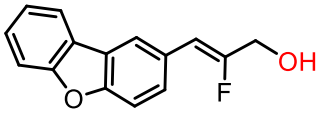
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.08 (d, *J* = 2.1 Hz, 1H), 6.97 (dd, *J* = 8.4, 2.1 Hz, 1H), 6.82 (d, *J* = 8.4 Hz, 1H), 5.65 (d, *J* = 38.5 Hz, 1H), 4.27 – 4.23 (m, 6H), 1.93 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -115.27 (dt, *J* = 38.5, 15.0 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.3 (d, *J* = 265.0 Hz), 143.4, 143.2 (d, *J* = 2.6 Hz), 126.4 (d, *J* = 2.8 Hz), 122.4 (d, *J* = 6.9 Hz), 117.6 (d, *J* = 7.9 Hz), 117.4, 107.3 (d, *J* = 6.8 Hz), 64.6, 64.5, 62.1 (d, *J* = 32.1 Hz).

EI-HRMS: mass spectrometry: m/z calcd for $C_{11}H_{11}O_3F$ $[M]^+$ 210.06922, measured 210.06862.

IR (neat, cm-1): ṽ: 3315, 2924, 2857, 1689, 1581, 1505, 1428, 1339, 1287, 1158, 1022, 881.



(*Z*)-3-(dibenzo[*b*,*d*]furan-2-yl)-2-fluoroprop-2-en-1-ol

2x: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 34 mg product was obtained by 70% isolated yield as yellow solid.

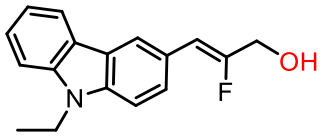
^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.07 (d, *J* = 1.7 Hz, 1H), 7.89 (broad d, *J* = 7.7, 1H), 7.54 – 7.49 (m, 2H), 7.46 (d, *J* = 8.5 Hz, 1H), 7.43 – 7.38 (m, 1H), 7.29 (td, *J* = 7.6 Hz, *J* = 1.0 Hz, 1H), 5.87 (d, *J* = 38.5 Hz, 1H), 4.28 (d, *J* = 15.2 Hz, 2H), 1.92 (broad s, 1H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -114.95 (dt, *J* = 38.6, 14.9 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.6 (d, *J* = 265.3 Hz), 156.7, 155.5 (d, *J* = 2.8 Hz), 128.3 (d, *J* = 6.6 Hz), 127.7 (d, *J* = 2.6 Hz), 127.5, 124.7, 124.2, 123.0, 120.9 (d, *J* = 8.2 Hz), 120.9, 111.9, 111.7, 107.7 (d, *J* = 6.8 Hz), 62.2 (d, *J* = 32.5 Hz).

EI-HRMS: mass spectrometry: m/z calcd for $C_{15}H_{11}O_2F$ $[M]^+$ 242.07431, measured 242.07353.

IR (neat, cm^{-1}): ṽ: 3353, 2921, 2853, 1685, 1536, 1450, 1343, 1287, 1200, 1153, 1016, 897, 740.



(*Z*)-3-(9-ethyl-9*H*-carbazol-3-yl)-2-fluoroprop-2-en-1-ol

2y: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 45 mg product was obtained by 84% isolated yield as yellow solid.

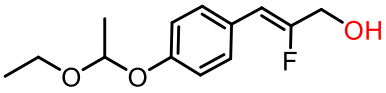
^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.18 (d, *J* = 1.6 Hz, 1H), 8.01 (d, *J* = 7.7 Hz, 1H), 7.55 (dd, *J* = 8.5, 1.7 Hz, 1H), 7.41 – 7.36 (m, 1H), 7.31 (d, *J* = 8.2 Hz, 1H), 7.26 (d, *J* = 8.5 Hz, 1H), 7.18 – 7.13 (m, 1H), 5.86 (d, *J* = 39.0 Hz, 1H), 4.30 – 4.21 (m, 4H), 1.89 (broad s, 1H), 1.34 (t, *J* = 7.3 Hz, 3H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -116.78 (dt, *J* = 39.1, 16.0 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 156.6 (d, *J* = 263.0 Hz), 140.4, 139.4 (d, *J* = 2.2 Hz), 126.9 (d, *J* = 6.8 Hz), 126.0, 123.7 (d, *J* = 2.6 Hz), 123.2, 123.1, 121.0 (d, *J* = 7.5 Hz), 120.6, 119.2, 108.7 (d, *J* = 6.9 Hz), 108.7, 108.5, 62.5 (d, *J* = 32.0 Hz), 37.7, 13.9.

EI-HRMS: mass spectrometry: m/z calcd for $C_{17}H_{16}ONF$ $[M]^+$ 269.12159, measured 269.12101.

IR (neat, cm^{-1}): ṽ: 3277, 2923, 2854, 1678, 1596, 1468, 1377, 1336, 1229, 1155, 1008, 894, 749.



(*Z*)-3-(4-(1-ethoxyethoxy)phenyl)-2-fluoroprop-2-en-1-ol

2z: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 34 mg product was obtained by 71% isolated yield as yellow solid.

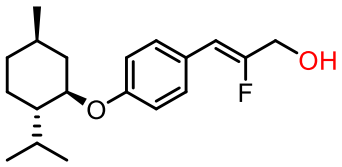
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.43 (d, *J* = 8.8 Hz, 2H), 6.96 (d, *J* = 8.8 Hz, 2H), 5.71 (d, *J* = 38.8 Hz, 1H), 5.39 (q, *J* = 5.3 Hz, 1H), 4.26 (d, *J* = 15.1 Hz, 2H), 3.78 (dq, *J* = 9.3, 7.1 Hz, 1H), 3.54 (dq, *J* = 9.3, 7.0 Hz, 1H), 2.03 (broad s, 1H), 1.50 (d, *J* = 5.3 Hz, 3H), 1.20 (t, *J* = 7.1 Hz, 3H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -115.66 (dt, *J* = 39.0, 15.3 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.2 (d, *J* = 265.1 Hz), 156.4 (d, *J* = 3.2 Hz), 130.1 (d, *J* = 7.7 Hz), 126.5 (d, *J* = 3.1 Hz), 117.4, 107.3 (d, *J* = 7.4 Hz), 99.6, 62.1 (d, *J* = 32.5 Hz), 61.6, 20.4, 15.3.

EI-HRMS: mass spectrometry: m/z calcd for $C_9H_9O_2F$ [M-alkyl fragment]$^+$ 168.05866, measured 168.05853 (molecular peak not stable under available ionization methods).

IR (neat, cm^{-1}): ṽ: 3155, 2927, 2857, 1693, 1608, 1511, 1439, 1342, 1222, 1163, 1020, 828.



(*Z*)-2-fluoro-3-(4-(((1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl)oxy)phenyl)prop-2-en-1-ol

2za: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 52 mg product was obtained by 85% isolated yield as yellow liquid.

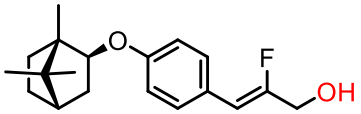
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.43 (d, *J* = 8.7 Hz, 2H), 6.87 (d, *J* = 8.8 Hz, 2H), 5.70 (d, *J* = 38.9 Hz, 1H), 4.26 (d, *J* = 15.4 Hz, 2H), 4.04 (td, *J* = 10.6 Hz, *J* = 4.1 Hz, 1H), 2.23 – 2.18 (m, 1H), 2.18 – 2.13 (m, 1H), 1.95 (s, 1H), 1.77 – 1.68 (m, 2H), 1.55 – 1.41 (m, 2H), 1.15 – 1.05 (m, 1H), 1.05 – 0.98 (m, 1H), 0.97 – 0.89 (m, 7H), 0.77 (d, *J* = 7.0 Hz, 3H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -116.41 (dt, *J* = 38.9, 15.4 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.9 (d, *J* = 2.9 Hz), 156.8 (d, *J* = 263.9 Hz), 130.2 (d, *J* = 7.2 Hz), 125.2 (d, *J* = 2.9 Hz), 115.8, 107.5 (d, *J* = 7.2 Hz), 77.7, 62.2 (d, *J* = 32.2 Hz), 48.2, 40.4, 34.6, 31.6, 26.2, 23.9, 22.3, 20.9, 16.7.

EI-HRMS: mass spectrometry: m/z calcd for $C_{19}H_{27}O_2F$ $[M]^+$ 306.19952, measured 306.19885.

IR (neat, cm^{-1}): ṽ: 3361, 2925, 2866, 1693, 1607, 1507, 1455, 1291, 1245, 1157, 1014, 858, 733.



(*Z*)-2-fluoro-3-(4-(((1*S*,2*S*,4*S*)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl)oxy)phenyl)prop-2-en-1-ol

2zb: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 15:1). 56 mg product was obtained by 92% isolated yield as yellow liquid.

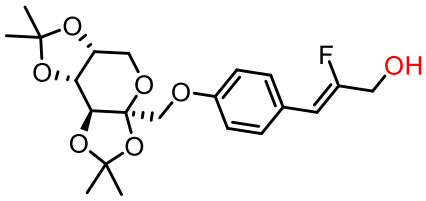
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.42 (d, *J* = 8.8 Hz, 2H), 6.81 (d, *J* = 8.7 Hz, 2H), 5.70 (d, *J* = 38.9 Hz, 1H), 4.33 (broad d, *J* = 8.4 Hz, 1H), 4.26 (d, *J* = 15.5 Hz, 2H), 2.41 – 2.32 (m, 1H), 2.26 – 2.20 (m, 1H), 1.93 (broad s, 1H), 1.79 – 1.72 (m, 2H), 1.38 – 1.30 (m, 1H), 1.29 – 1.24 (m, 1H), 1.11 (dd, *J* = 13.3, 3.4 Hz, 1H), 0.95 (s, 3H), 0.93 (s, 3H), 0.92 (s, 3H).

^{19}F NMR (565 MHz, Chloroform-*d*) δ -116.54 (dt, *J* = 39.1, 15.7 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 158.7 (d, *J* = 2.9 Hz), 156.7 (d, *J* = 263.5 Hz), 130.1 (d, *J* = 7.2 Hz), 124.9 (d, *J* = 2.9 Hz), 115.6, 107.6 (d, *J* = 7.2 Hz), 83.0, 62.3 (d, *J* = 32.0 Hz), 49.6, 47.7, 45.3, 37.0, 28.1, 26.9, 19.9, 19.1, 13.9.

EI-HRMS: mass spectrometry: m/z calcd for $C_{19}H_{25}O_2F$ $[M]^+$ 304.18386, measured 304.18317.

IR (neat, cm^{-1}): ṽ: 3352, 2948, 2876, 1694, 1607, 1508, 1454, 1366, 1296, 1248, 1157, 1024, 858.



(*Z*)-2-fluoro-3-(4-(((3a*S*,5a*R*,8a*R*,8b*S*)-2,2,7,7-tetramethyltetrahydro-3a*H*-bis([1,3]dioxolo)[4,5-*b*:4',5'-*d*]pyran-3a-yl)methoxy)phenyl)prop-2-en-1-ol

2zc: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 8:1). 65 mg product was obtained by 79% isolated yield as yellow solid.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.43 (d, *J* = 8.8 Hz, 2H), 6.89 (d, *J* = 8.8 Hz, 2H), 5.70 (d, *J* = 38.9 Hz, 1H), 4.64 (dd, *J* = 7.9, 2.6 Hz, 1H), 4.54 (d, *J* = 2.6 Hz, 1H), 4.29 – 4.22 (m, 3H), 4.16 (d, *J* = 10.1 Hz, 1H), 4.04 (d, *J* = 10.1 Hz, 1H), 3.97 (dd, *J* = 13.0, 1.9 Hz, 1H), 3.79 (d, *J* = 13.0 Hz, 1H), 2.04 (broad s, 1H), 1.56 (s, 3H), 1.49 (s, 3H), 1.48 (s, 3H), 1.34 (s, 3H).

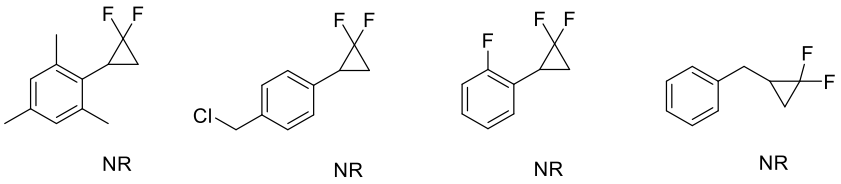
^{19}F NMR (565 MHz, Chloroform-*d*) δ -115.84 (dt, *J* = 38.7, 15.1 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 157.9 (d, *J* = 2.7 Hz), 157.1 (d, *J* = 264.2 Hz), 130.1 (d, *J* = 7.2 Hz), 126.0 (d, *J* = 2.7 Hz), 114.8, 109.2, 109.1, 107.2 (d, *J* = 7.1 Hz), 102.3, 71.1, 70.3, 70.1, 68.9, 62.1 (d, *J* = 32.3 Hz), 61.3, 26.7, 26.1, 25.5, 24.1.

EI-HRMS: mass spectrometry: m/z calcd for $C_{21}H_{27}O_7F$ $[M]^+$ 410.17408, measured 410.17298.

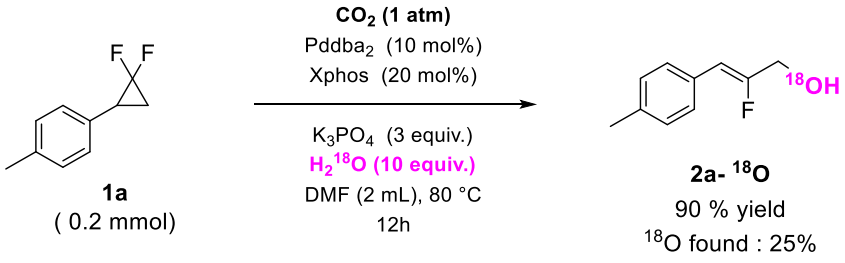
IR (neat, cm^{-1}): ṽ: 3315, 2922, 2853, 2158, 1659, 1632, 1510, 1458, 1377, 1295, 1162, 1066, 1019, 863.

5. Selected unsuccessful substrates.



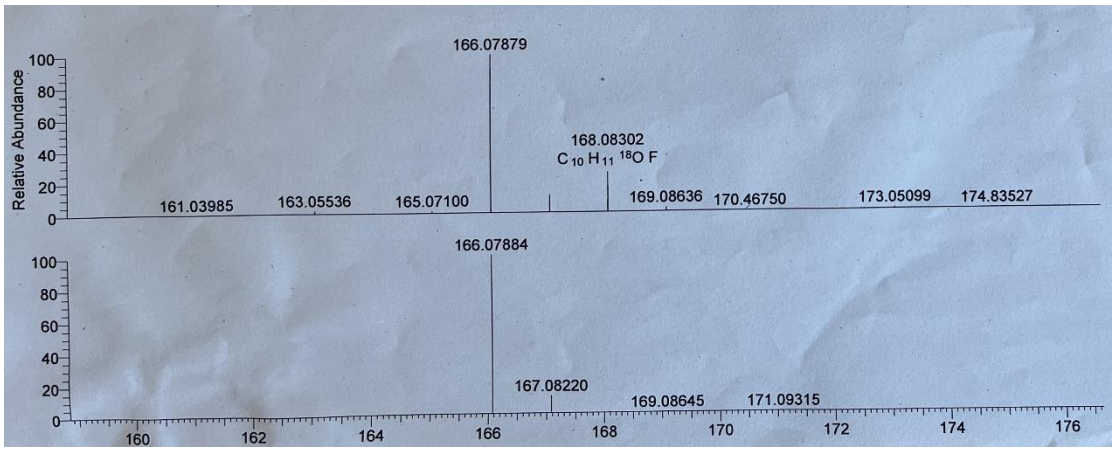
6. ^{18}O-label experiment.

6.1 Under optimized conditions

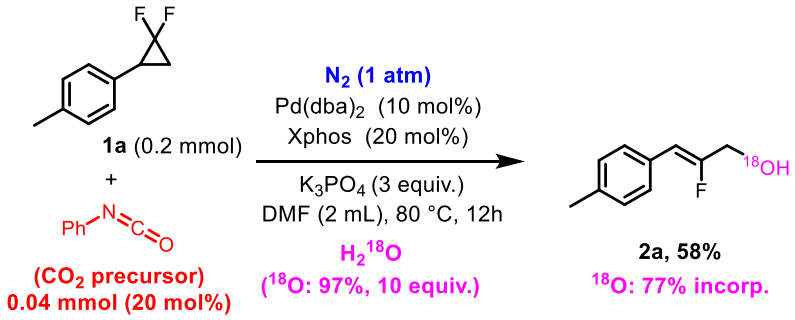


Xphos (19.1 mg, 0.04 mmol) and $Pd(dba)_2$ (11.4 mg, 0.02 mmol), *gem*-difluorocyclopropane **1a** (0.2 mmol), **$H_2{}^{18}O$** (10.0 equiv., 36 mg), K_3PO_4 (3.0 equiv., 127.2 mg) were dissolved in 2 mL DMF and CO_2 was bubbled through the solution for about two minutes. Then, the mixture was sealed under CO_2 (1 atm) and stirred at 80 °C for about 12h, until the starting material was consumed (monitored by TLC). Then, the mixture was filtered through celite and the filtrate was concentrated to dryness. The crude was purified by column chromatography to give the product **2a-^{18}O**.

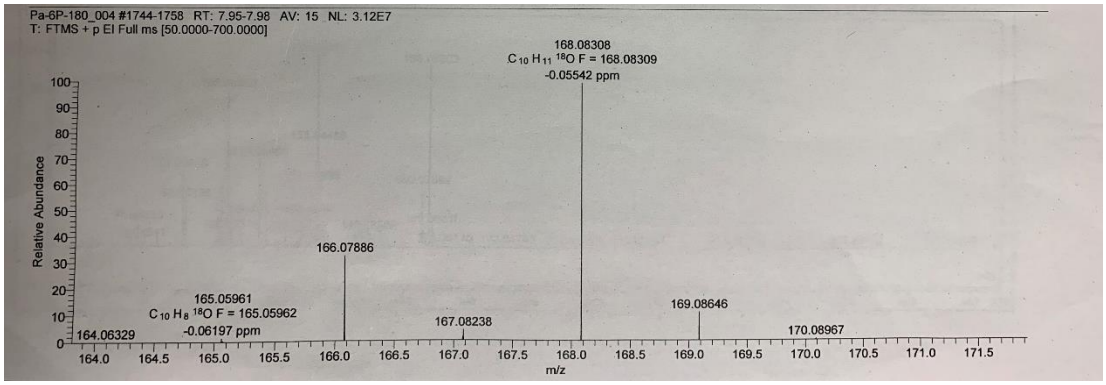
EI-HRMS: mass spectrometry: m/z calcd for $C_{10}H_{11}{}^{18}OF$ $[M]^+$ 168.08364, measured 168.08302.



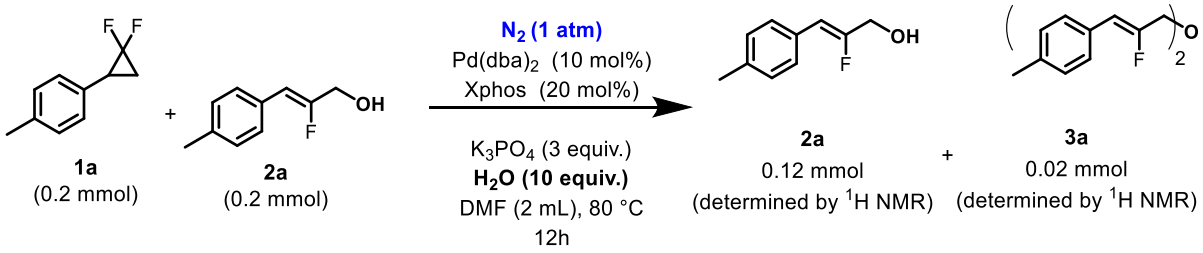
6.2 Under CO_2 catalyzed conditions



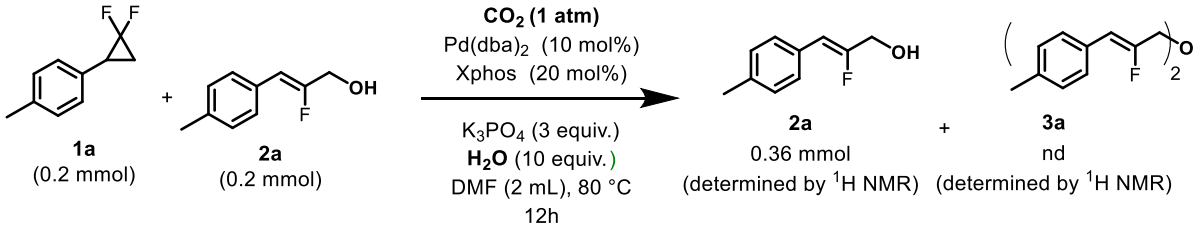
Xphos (19.1 mg, 0.04 mmol) and $Pd(dba)_2$ (11.4 mg, 0.02 mmol), phenyl isocyanate (4.8 mg, 0.04 mmol), *gem*-difluorocyclopropane **1a** (0.2 mmol), **$H_2{}^{18}O$** (10.0 equiv., 36 mg), K_3PO_4 (3.0 equiv., 127.2 mg) were dissolved in 2 mL DMF and N_2 was bubbled through the solution for about two minutes. Then the mixture was stirred under N_2 (1 atm) at 80 °C for about 12 h until the starting material was consumed (monitored by TLC). The mixture was then filtered through celite and the filtrate was concentrated to dryness. The crude was purified by column chromatography to give the products **2a-^{18}O**.



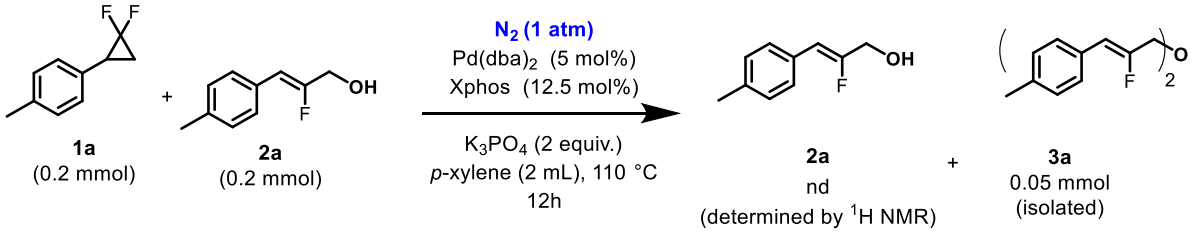
7. Double C─O bond forming experiments.



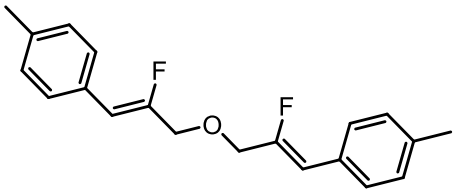
Xphos (19.1 mg, 0.04 mmol) and $Pd(dba)_2$ (11.4 mg, 0.02 mmol), *gem*-difluorocyclopropane **1a** (0.2 mmol), **2a** (0.2 mmol), H_2O (10.0 equiv., 36 mg), K_3PO_4 (3.0 equiv., 127.2 mg) were dissolved in 2 mL DMF and N_2 was bubbled through the solution for about two minutes. Then the mixture was stirred under N_2 (1 atm) at 80 °C for about 12 h until the starting material was consumed (monitored by TLC). The mixture was then filtered through celite and the filtrate was concentrated to dryness and analyzed by NMR using 1,3,5-trimethoxybenzene as an internal standard.



Xphos (19.1 mg, 0.04 mmol) and $Pd(dba)_2$ (11.4 mg, 0.02 mmol), *gem*-difluorocyclopropane **1a** (0.2 mmol), **2a** (0.2 mmol), H_2O (10.0 equiv., 36 mg), K_3PO_4 (3.0 equiv., 127.2 mg) were dissolved in 2 mL DMF and CO_2 was bubbled through the solution for about two minutes. Then the mixture was stirred under CO_2 (1 atm) at 80 °C for about 12 h until the starting material was consumed (monitored by TLC). The mixture was then filtered through celite and the filtrate was concentrated to dryness and analyzed by NMR using 1,3,5-trimethoxybenzene as an internal standard.



Xphos (11.9 mg, 0.025 mmol) and $Pd(dba)_2$ (5.7 mg, 0.01 mmol), *gem*-difluorocyclopropane **1a** (0.2 mmol), **2a** (0.2 mmol), K_3PO_4 (2.0 equiv., 84.8 mg) were dissolved in 2 mL *p*-xylene and N_2 was bubbled through the solution for about two minutes. Then the mixture was stirred under N_2 (1 atm) at 110 °C for about 12 h until the starting material was consumed (monitored by TLC). The mixture was then filtered through celite and the filtrate was concentrated to dryness. The crude was purified by column chromatography to give the product **3a**.



4,4'-((1*Z*,1'*Z*)-oxybis(2-fluoroprop-1-ene-3,1-diyl))bis(methylbenzene)

3a: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 50:1). 16 mg product was obtained by 25% isolated yield as yellow liquid.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.42 (d, *J* = 8.2 Hz, 4H), 7.16 (d, *J* = 8.0 Hz, 4H), 5.78 (d, *J* = 38.4 Hz, 2H), 4.23 (d, *J* = 16.2 Hz, 4H), 2.35 (s, 6H).

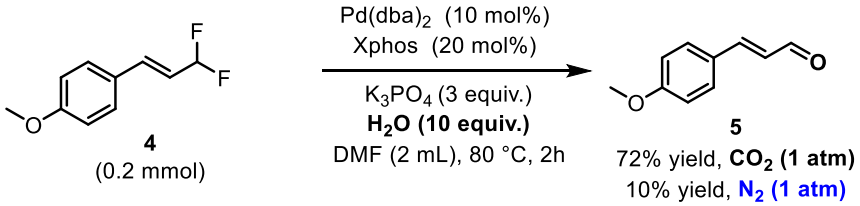
^{19}F NMR (565 MHz, Chloroform-*d*) δ -111.88 (dt, *J* = 38.2, 16.2 Hz).

^{13}C NMR (151 MHz, Chloroform-*d*) δ 155.2 (d, *J* = 266.9 Hz), 137.7 (d, *J* = 2.4 Hz), 129.8 (d, *J* = 2.9 Hz), 129.4, 128.9 (d, *J* = 7.2 Hz), 109.9 (d, *J* = 6.7 Hz), 68.9 (d, *J* = 30.8 Hz), 21.4.

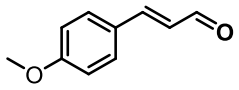
ESI-HRMS: mass spectrometry: m/z calcd for $C_{20}H_{20}OF_2Na$ $[M+Na]^+$ 337.13744, measured 337.13824.

IR (neat, cm^{-1}): ṽ: 3356, 2924, 2051, 1635, 1513, 1452, 1351, 1249, 1160, 1077, 861, 809.

8. Product 5



Xphos (19.1 mg, 0.04 mmol) and $Pd(dba)_2$ (11.4 mg, 0.02 mmol), **4** (0.2 mmol), H_2O (10.0 equiv., 36 mg), K_3PO_4 (3.0 equiv., 127.2 mg) were dissolved in 2 mL DMF and CO_2 was bubbled through the solution for about two minutes. Then the mixture was stirred under CO_2 (1 atm) at 80 °C for about 2 h until the starting material was consumed (monitored by TLC). The mixture was then filtered through celite and the filtrate was concentrated to dryness. The crude was purified by column chromatography to give the product **5**.



(*E*)-3-(4-methoxyphenyl)acrylaldehyde

5: The crude mixture was purified by SiO_2 gel column chromatography with pentane/EA (from 20:1). 23.3 mg product was obtained by 72% isolated yield as colorless solid.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 9.67 (d, *J* = 7.8 Hz, 1H), 7.58 – 7.50 (m, 2H), 7.44 (d, *J* = 15.9 Hz, 1H), 6.96 (d, *J* = 8.7 Hz, 2H), 6.63 (dd, *J* = 15.8, 7.7 Hz, 1H), 3.88 (s, 3H).

Data in accordance with the literature.[S7]

9. References

[S1] J. Xu, E. A. Ahmed, B. Xiao, Q. Q. Lu, Y. L. Wang, C. G. Yu, Y. Fu, *Angew. Chem. Int. Ed.* **2015**, *54*, 8231.

[S2] L. Y. Lv, C. J. Li, *Angew. Chem. Int. Ed.* **2021**, *60*, 13098.

[S3] L. Wu, M. Wang, Y. Liang, Z. Z. Shi, *Chin. J. Chem.* **2022**, *40*, 2345.

[S4] W. Yu, S. Wang, M. He, Z. Jiang, Y. Yu, J. Lan, J. Luo, P. Wang, X. Qi, T. Wang, A. Lei, *Angew. Chem. Int. Ed.* **2023,** *62*, e202219166.

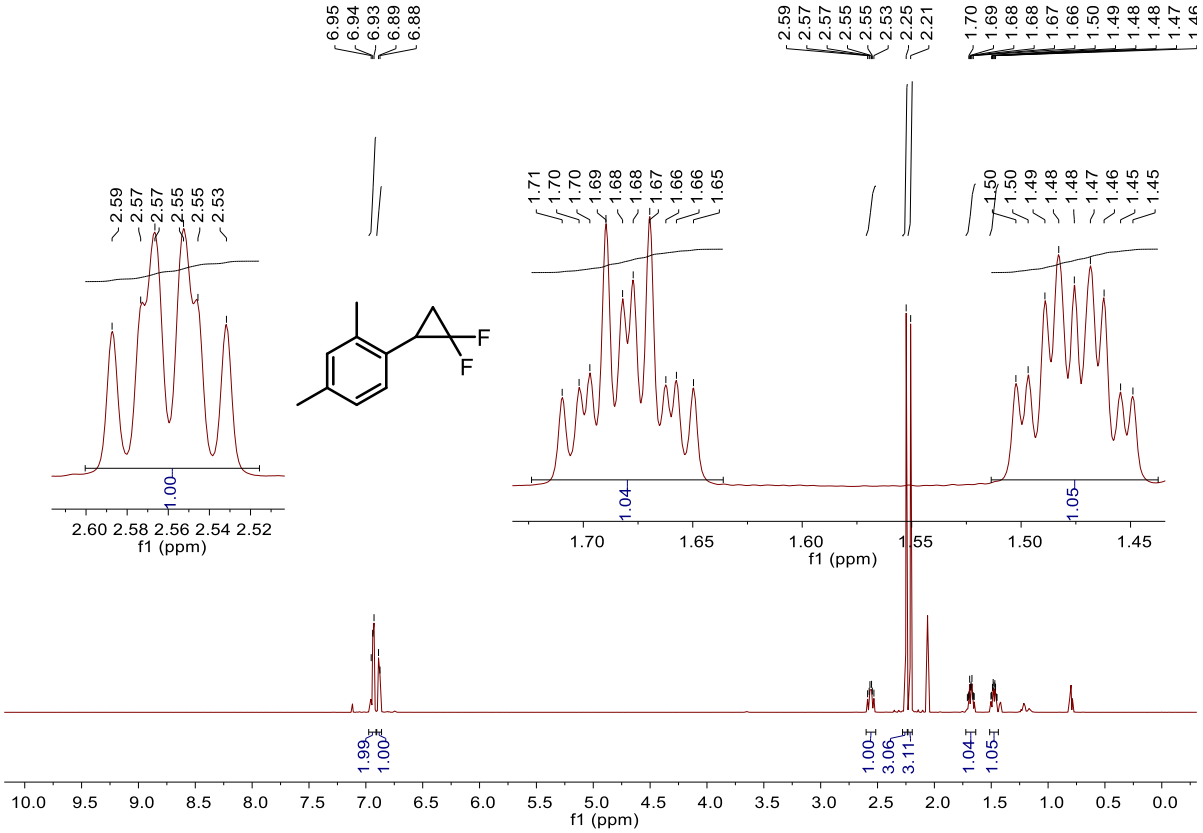
[S5] H. R. A. Golf, H.-U. Reissig, A. Wiehe, *Eur. J. Org. Chem.* **2015**, 1548.

[S6] B. Xiong, X. Chen, J. Liu, X. Zhang, Y. Xia, Z. Lian, *ACS Catal*. **2021**, *11*, 11960.

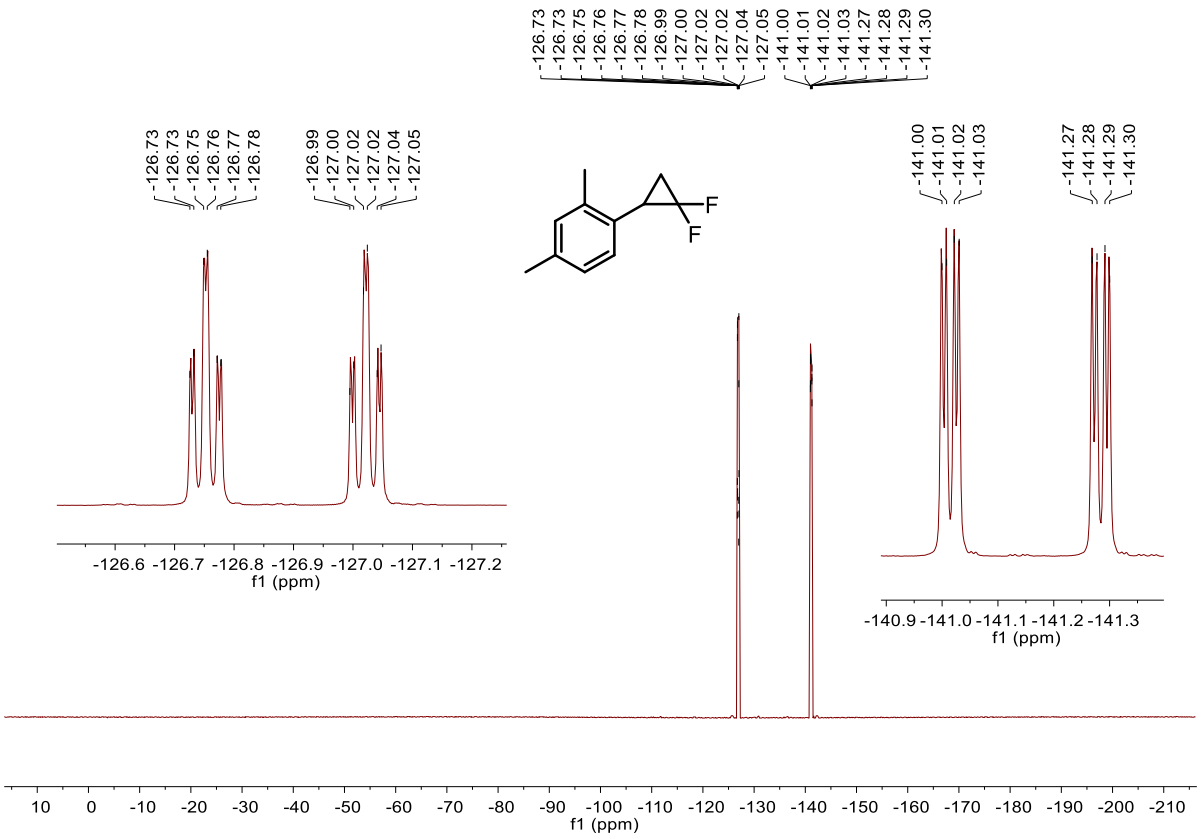
[S7] Y. Hayashi, T. Itoh, H. Ishikawa, *Adv. Synth. Catal.* **2013**, *355*, 3661.

10. Copies of ^{1}H, ^{13}C and ^{19}F NMR spectra

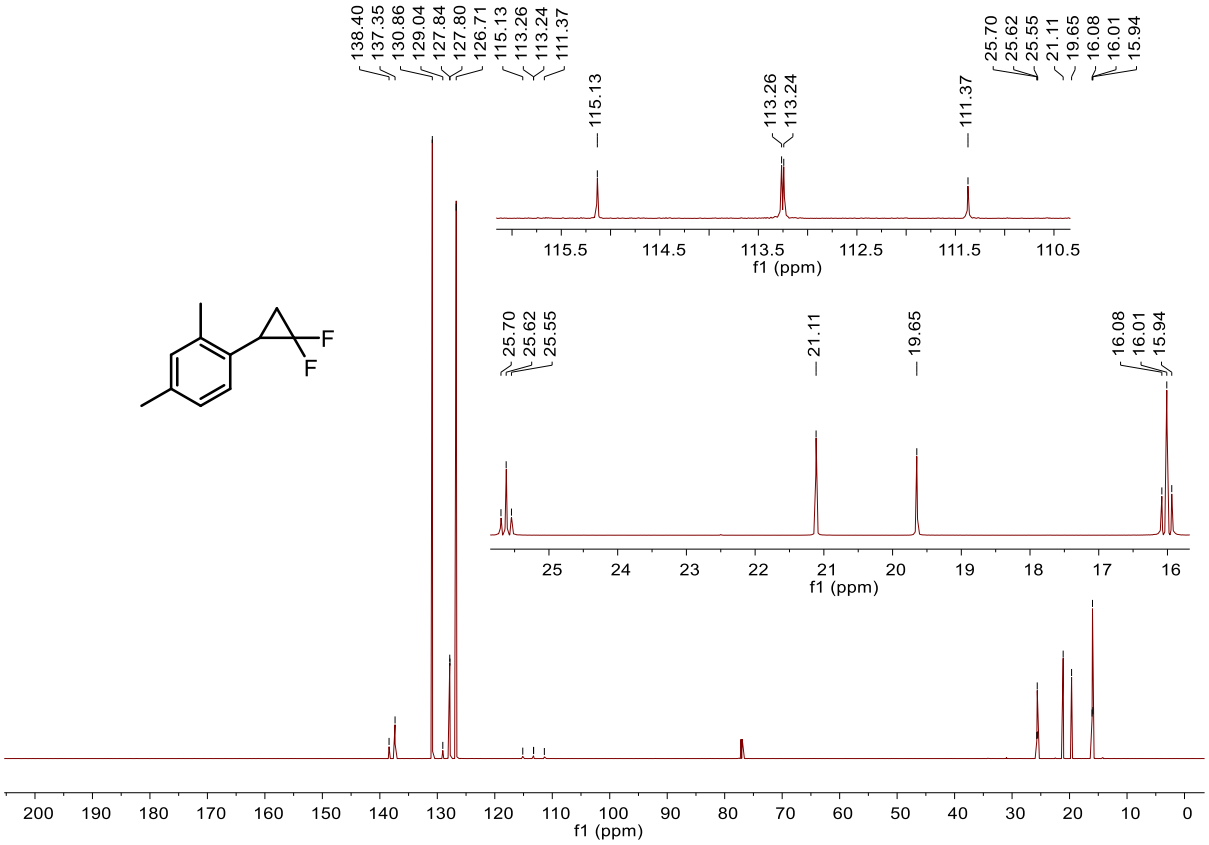
^{1}H NMR (substrate **1p**)



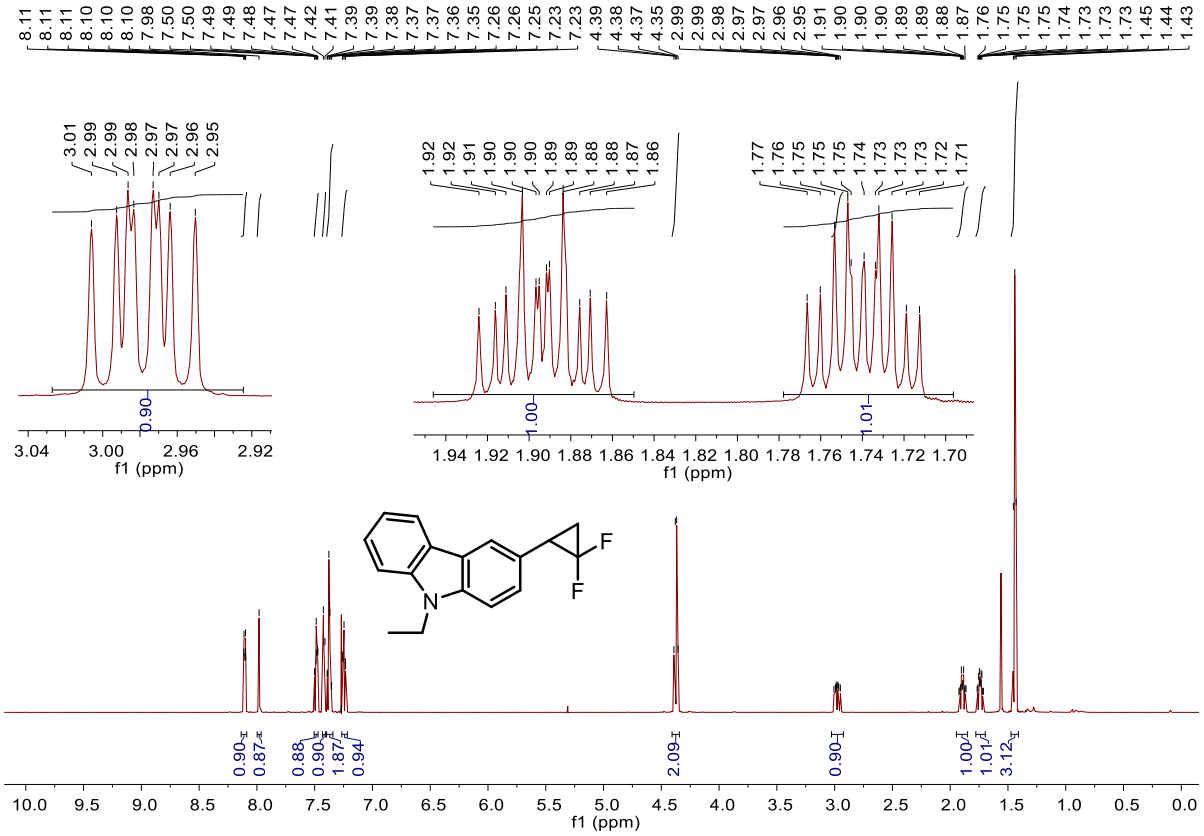
^{19}F NMR (substrate **1p**)



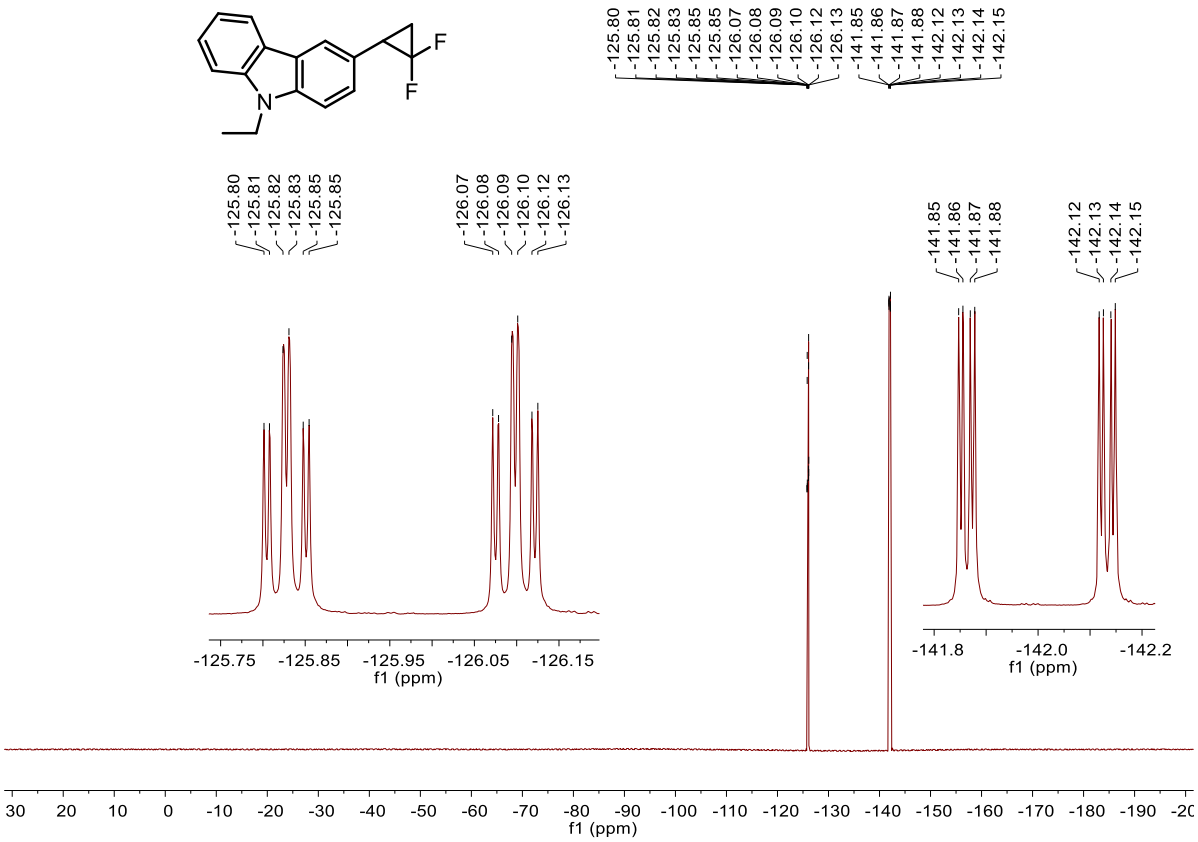
^{13}C NMR (substrate **1p**)



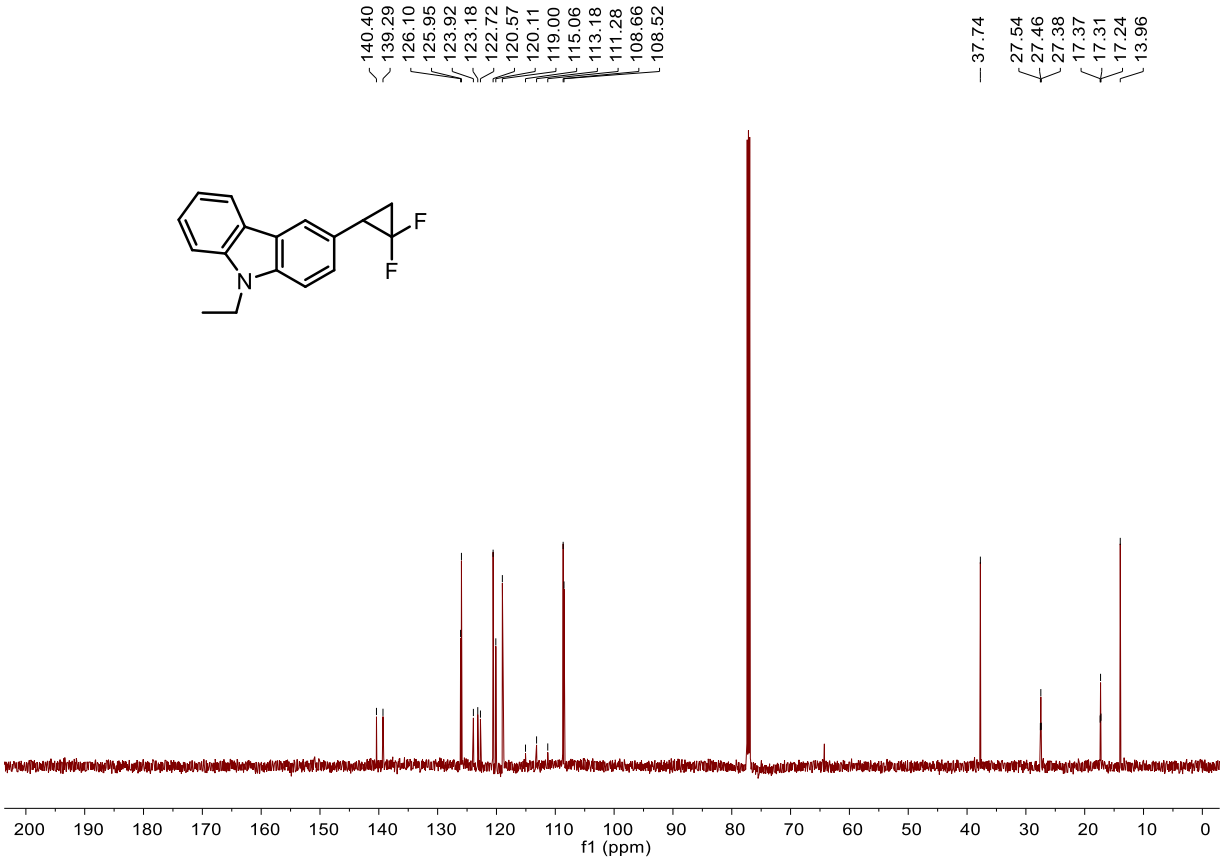
^{1}H NMR (substrate **1y**)



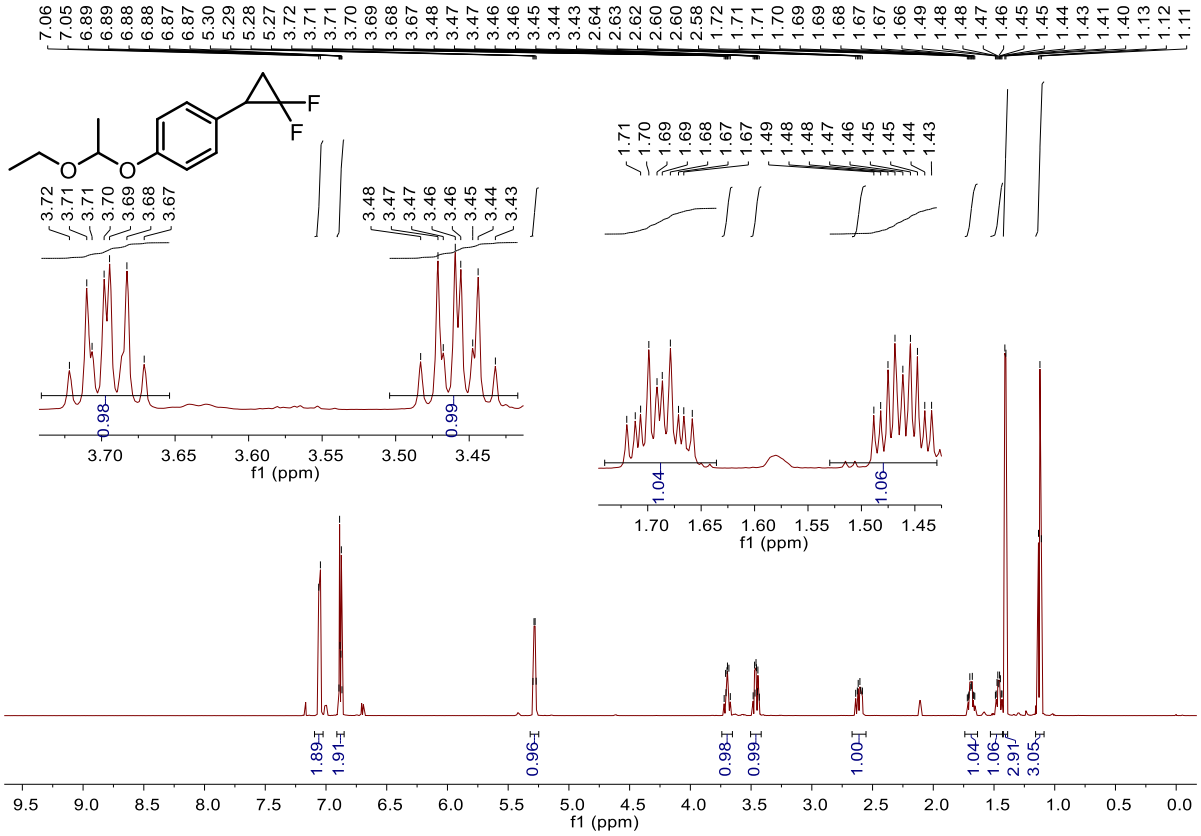
^{19}F NMR (substrate **1y**)



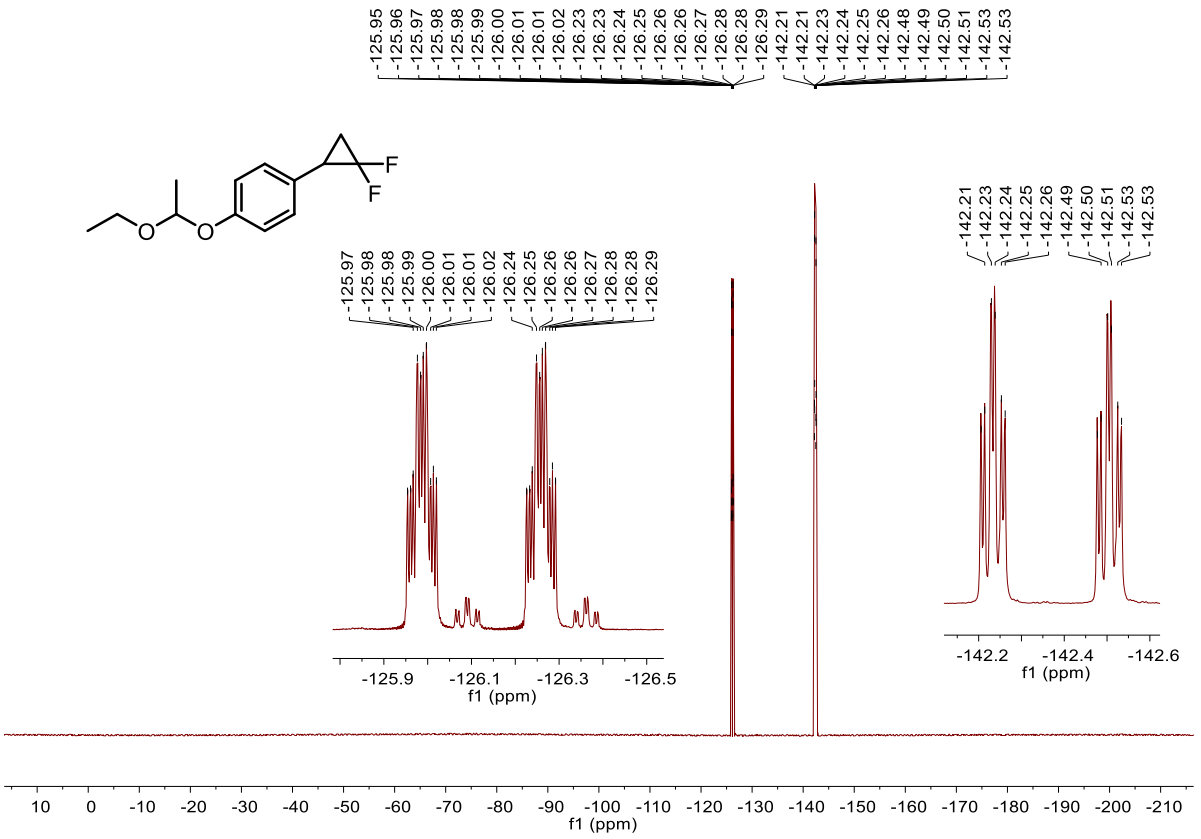
^{13}C NMR (substrate **1y**)



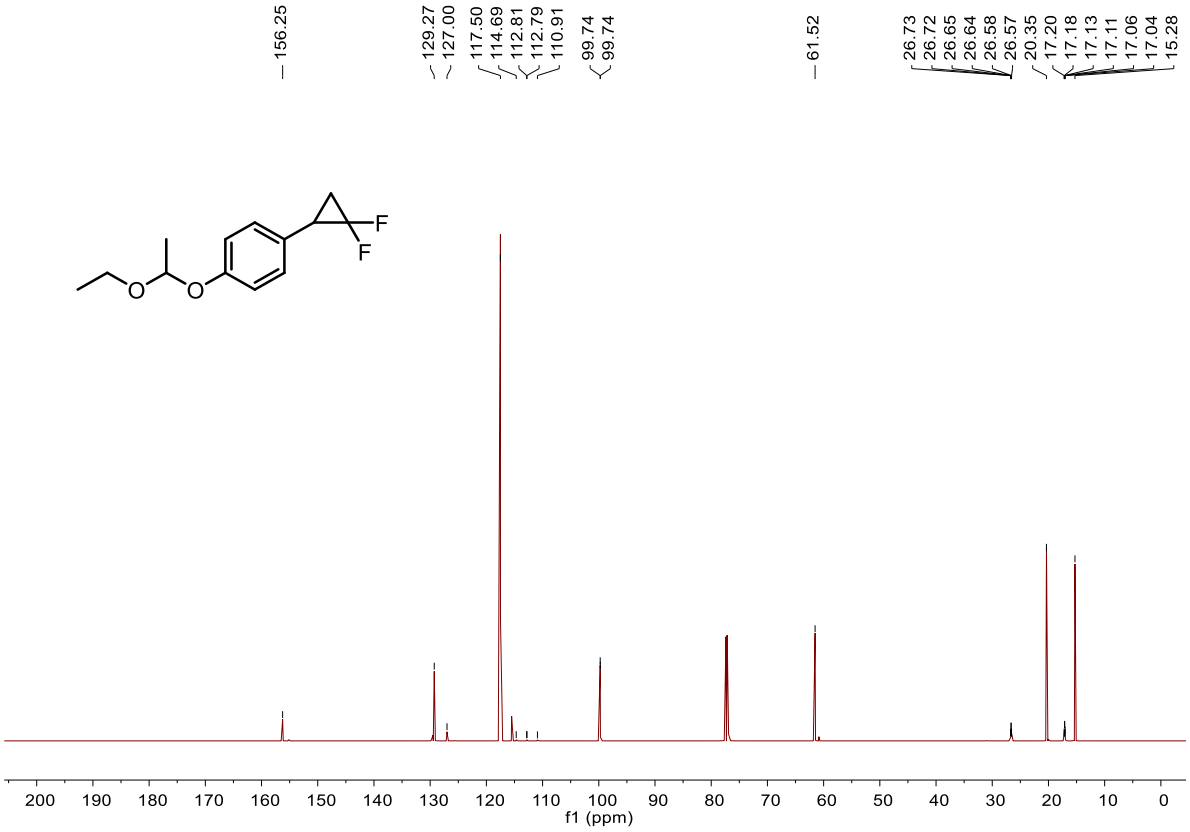
^{1}H NMR (substrate **1z**)



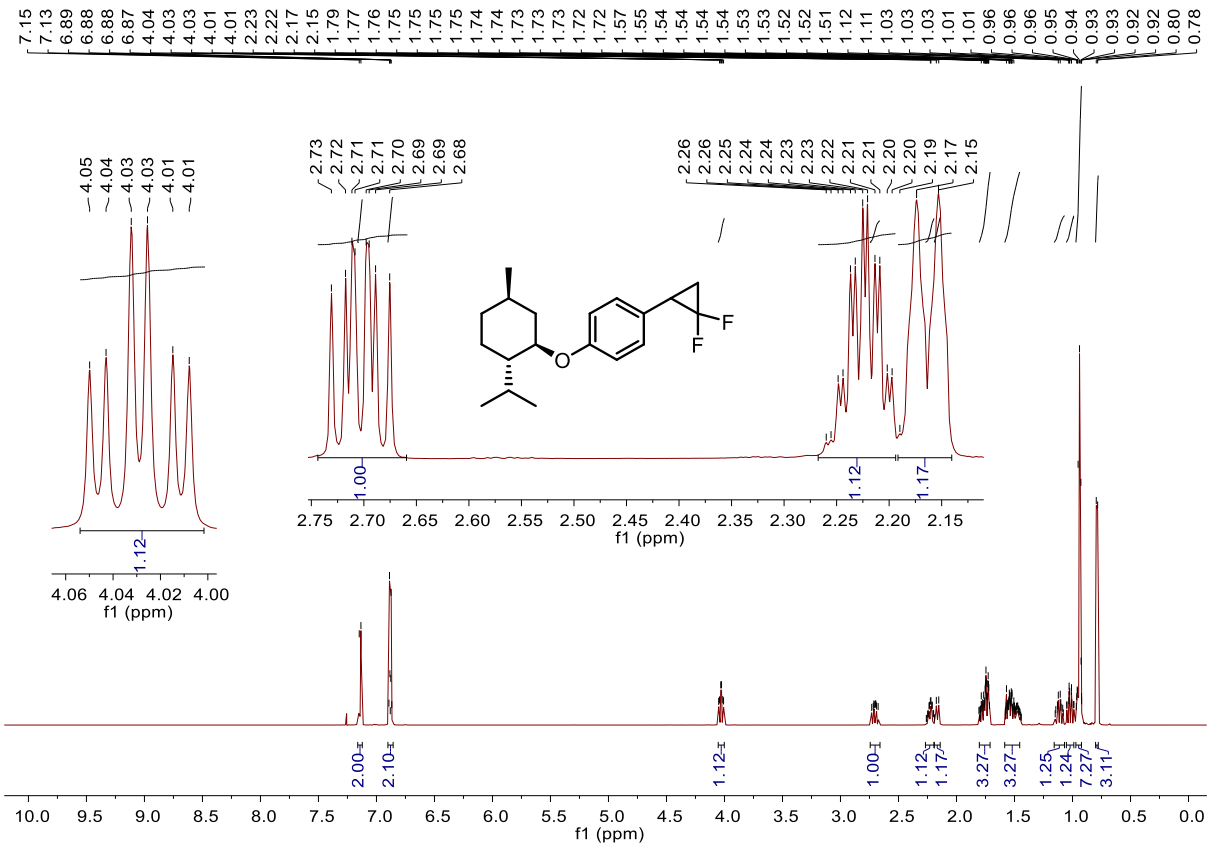
^{19}F NMR (substrate **1z**)



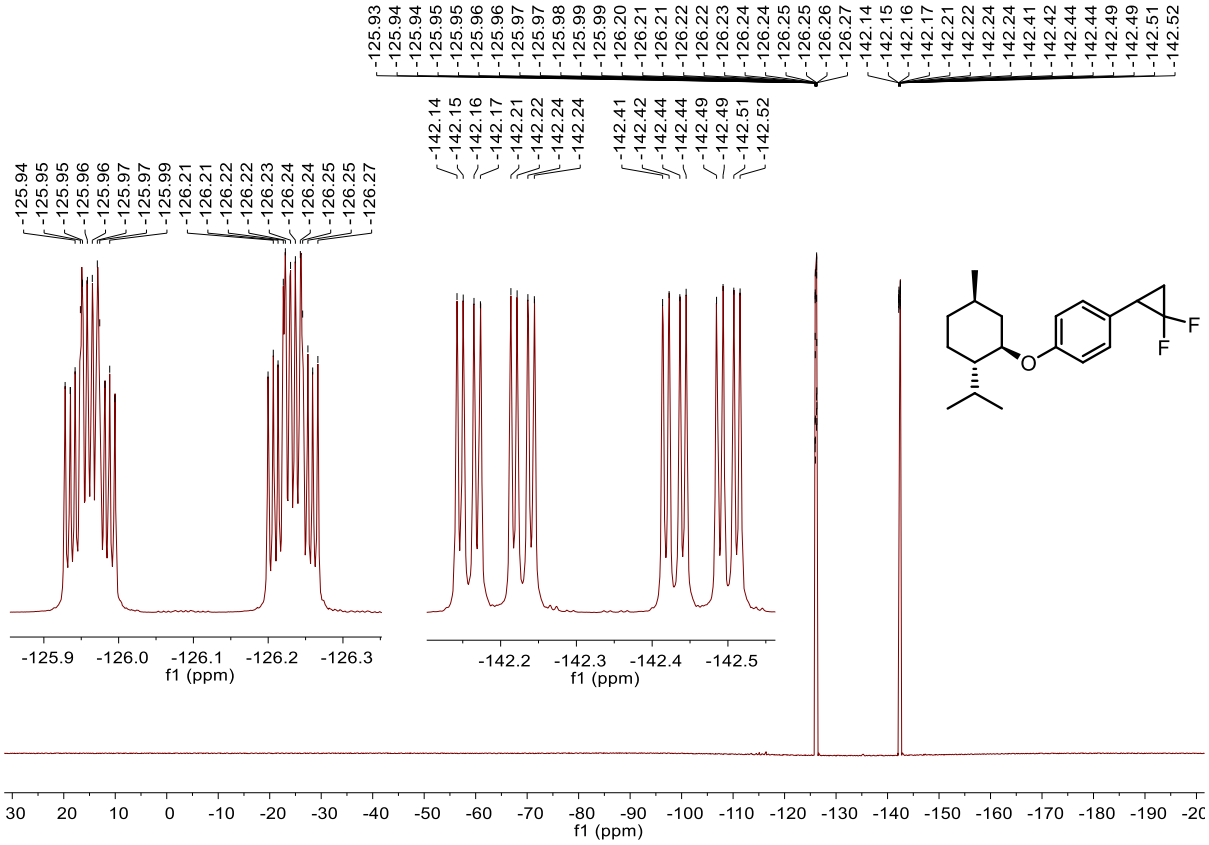
^{13}C NMR (substrate **1z**)



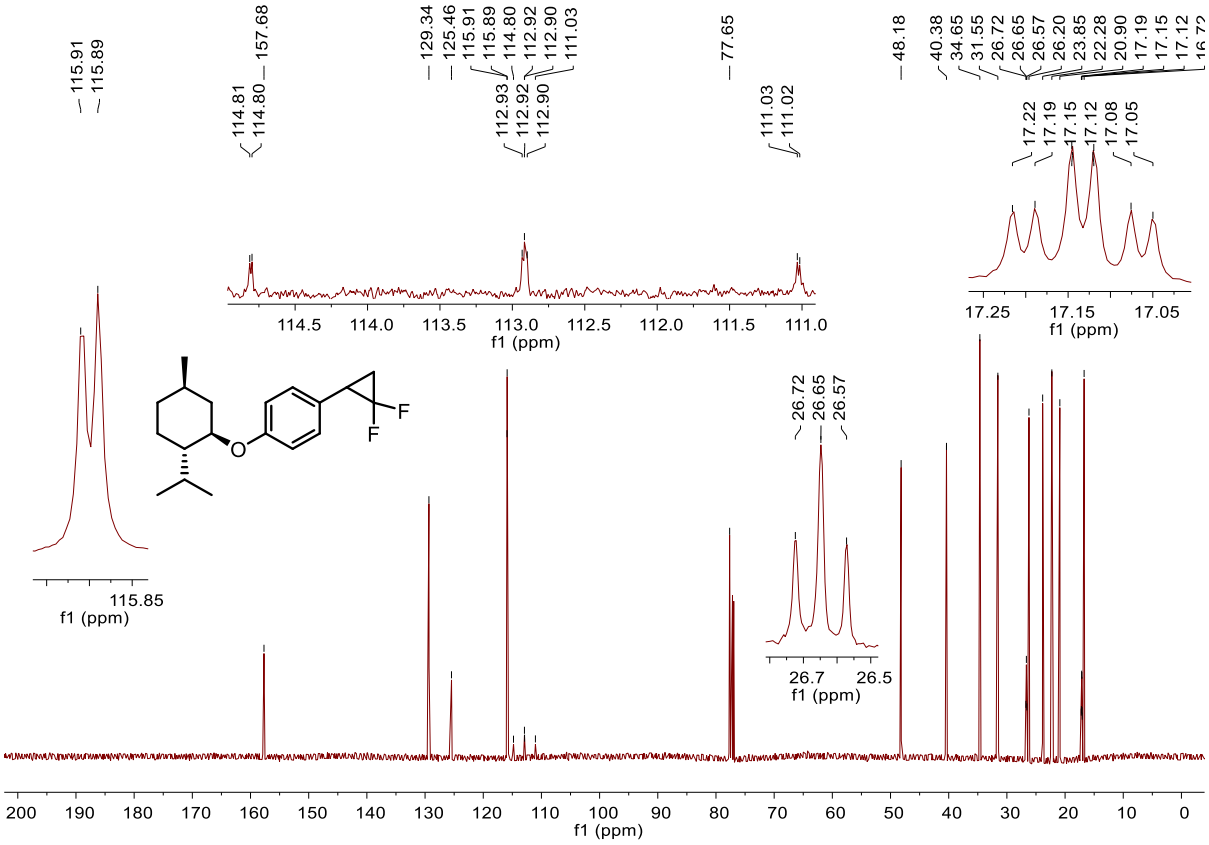
^{1}H NMR (substrate **1za**)



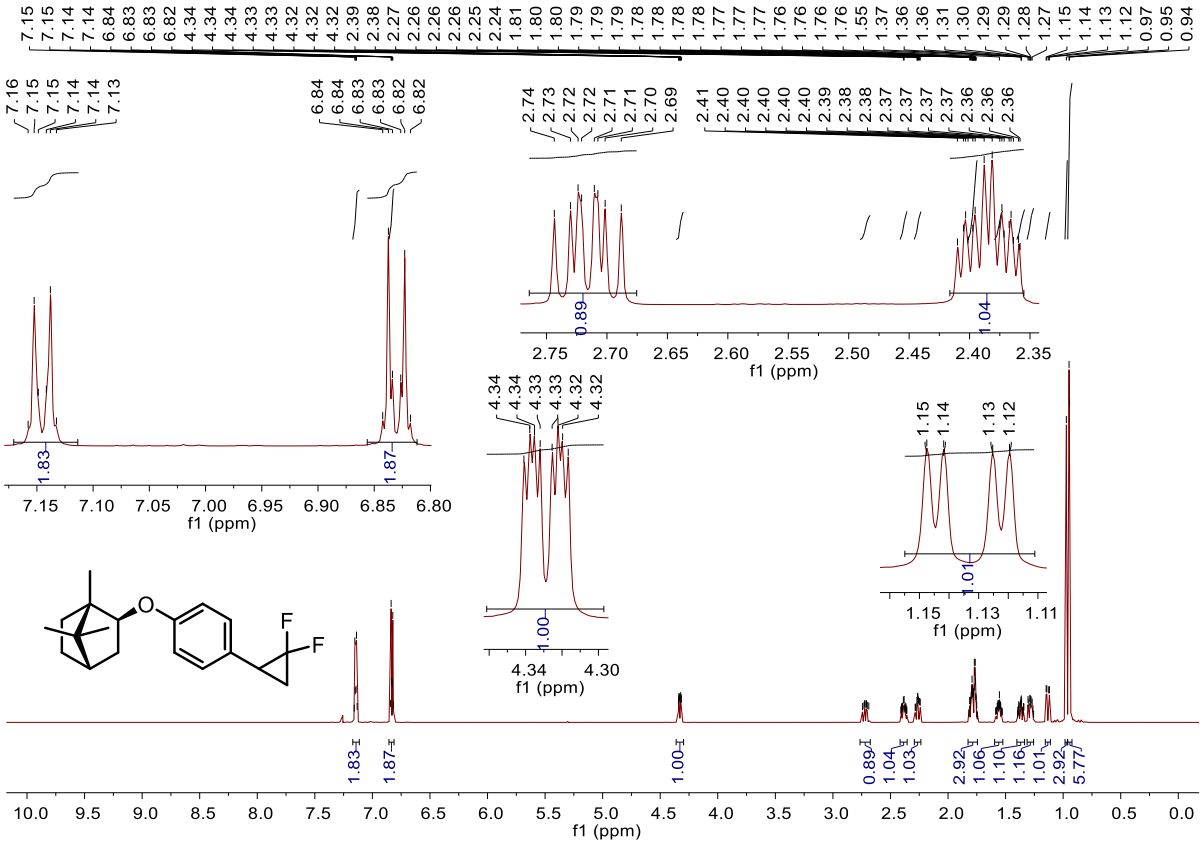
^{19}F NMR (substrate **1za**)



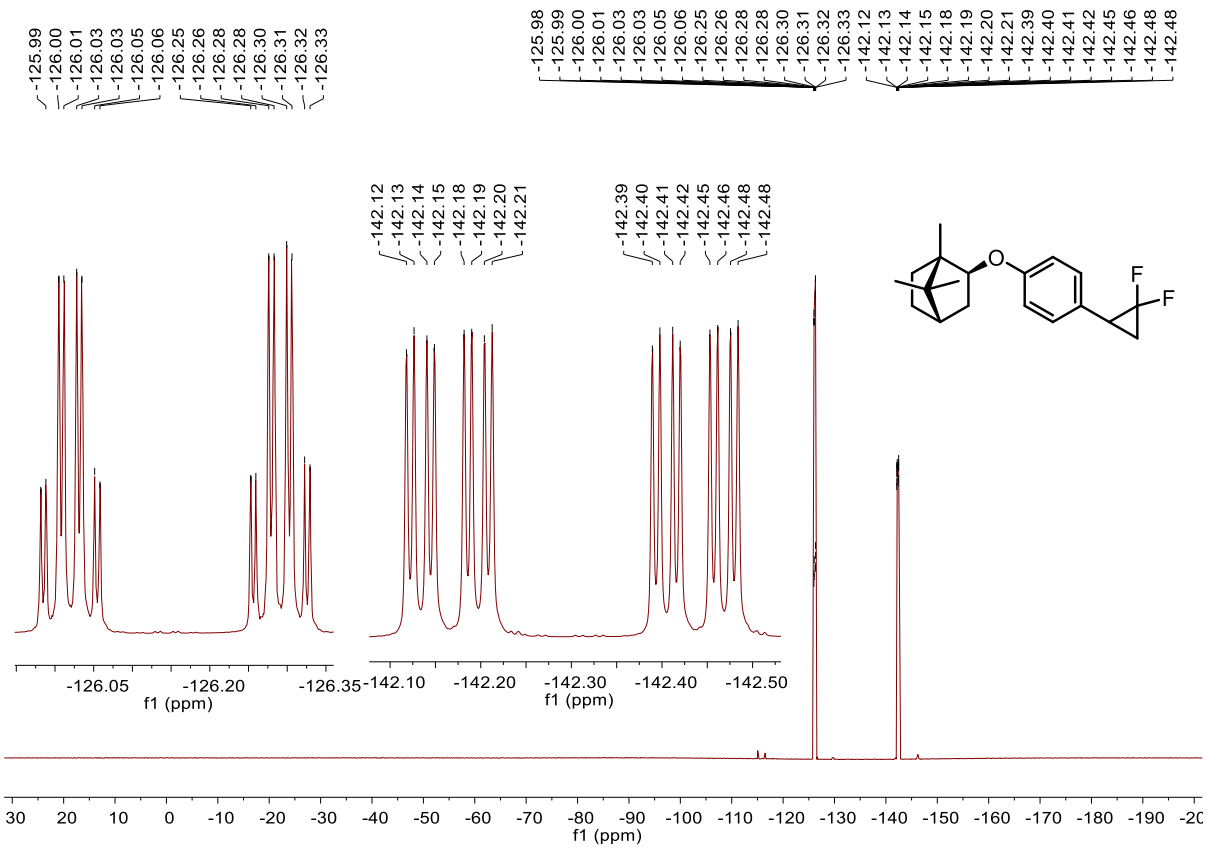
^{13}C NMR (substrate **1za**)



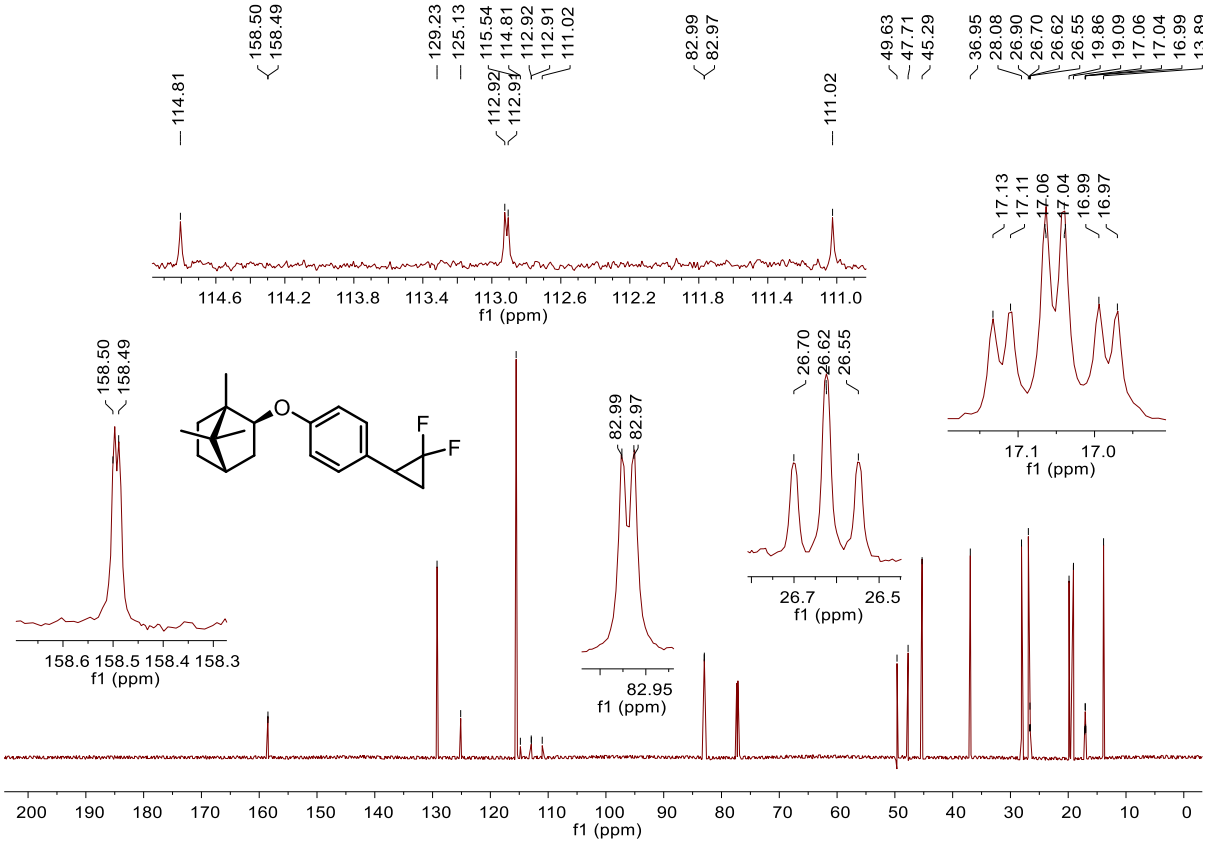
^{1}H NMR (substrate **1zb**)



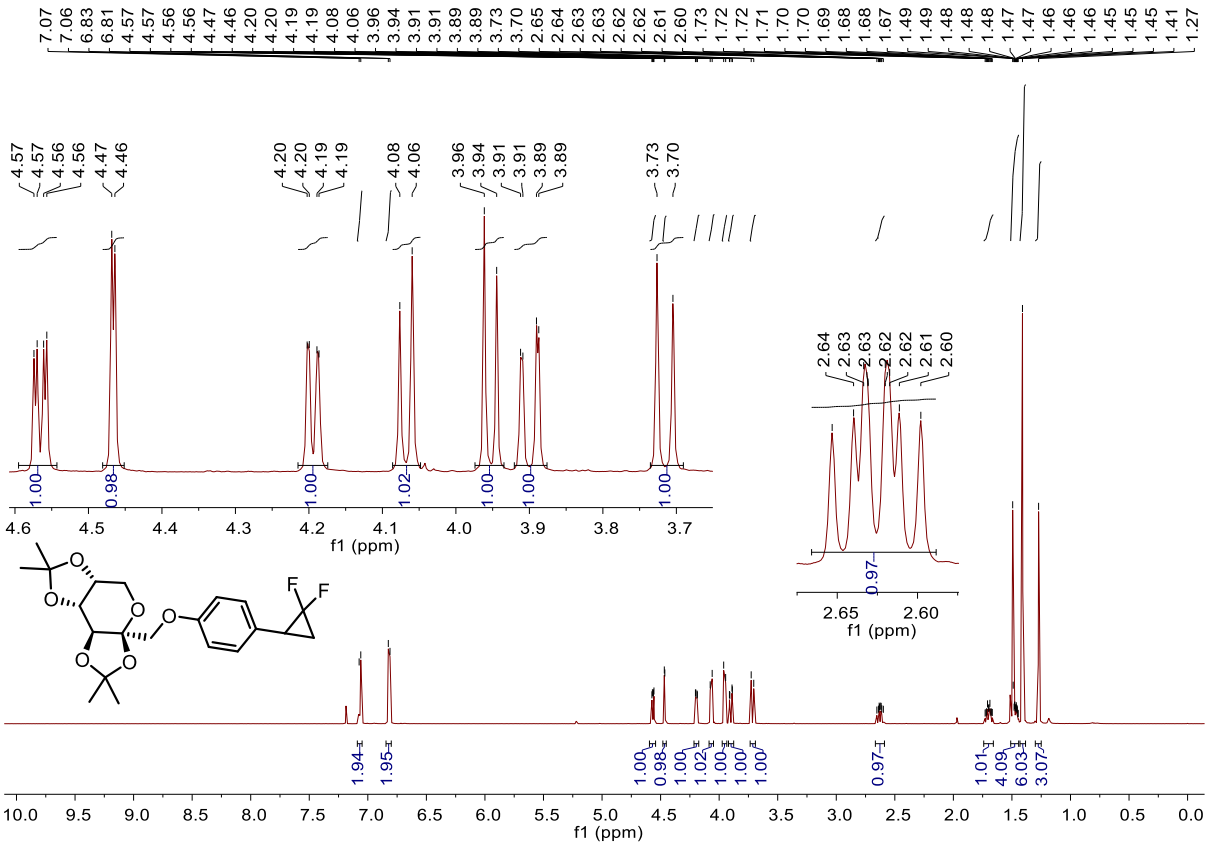
^{19}F NMR (substrate **1zb**)



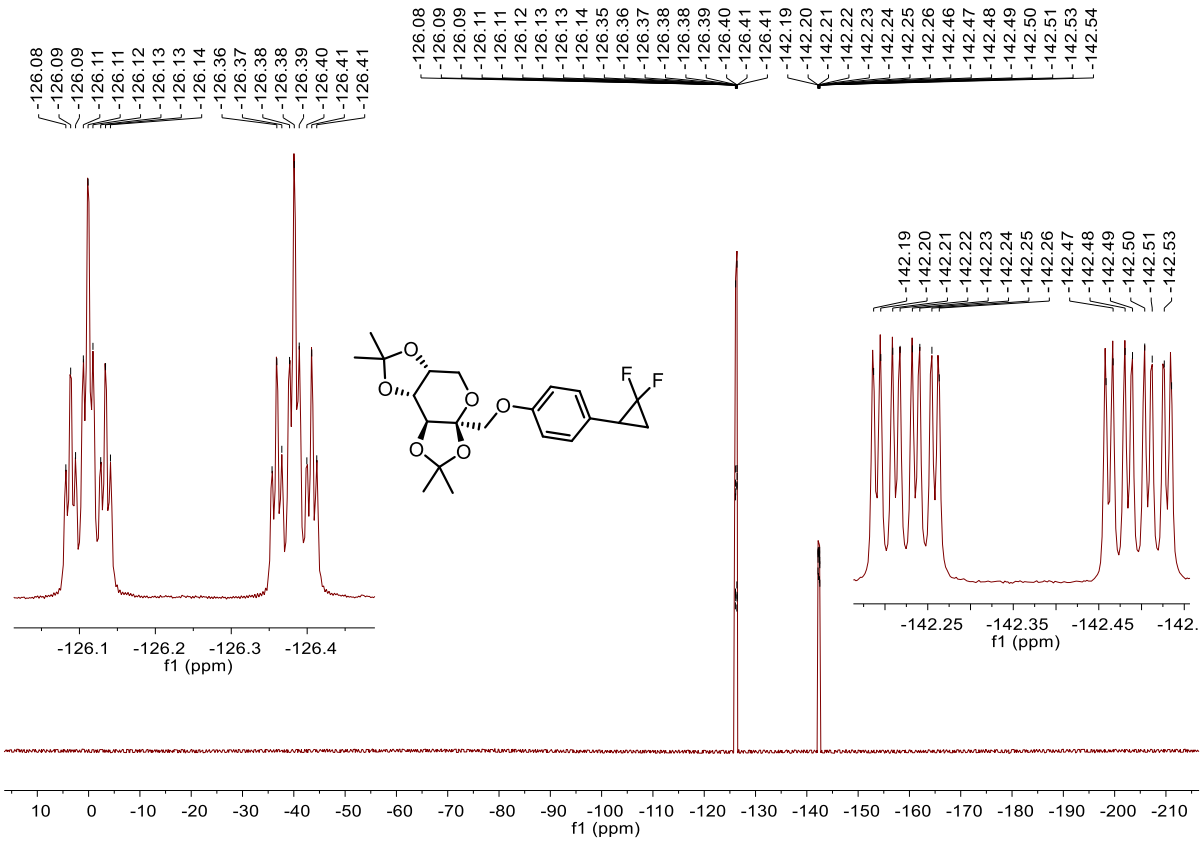
^{13}C NMR (substrate **1zb**)



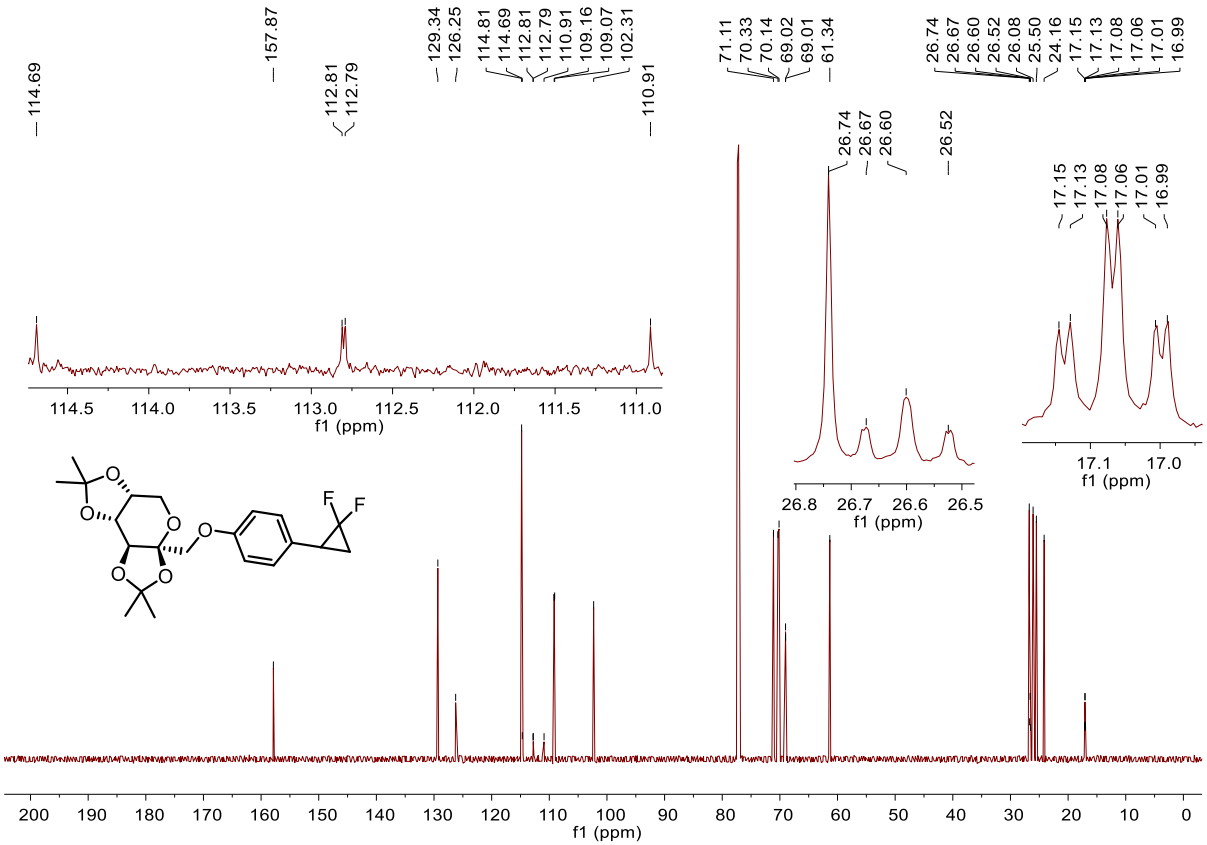
^{1}H NMR (substrate **1zc**)



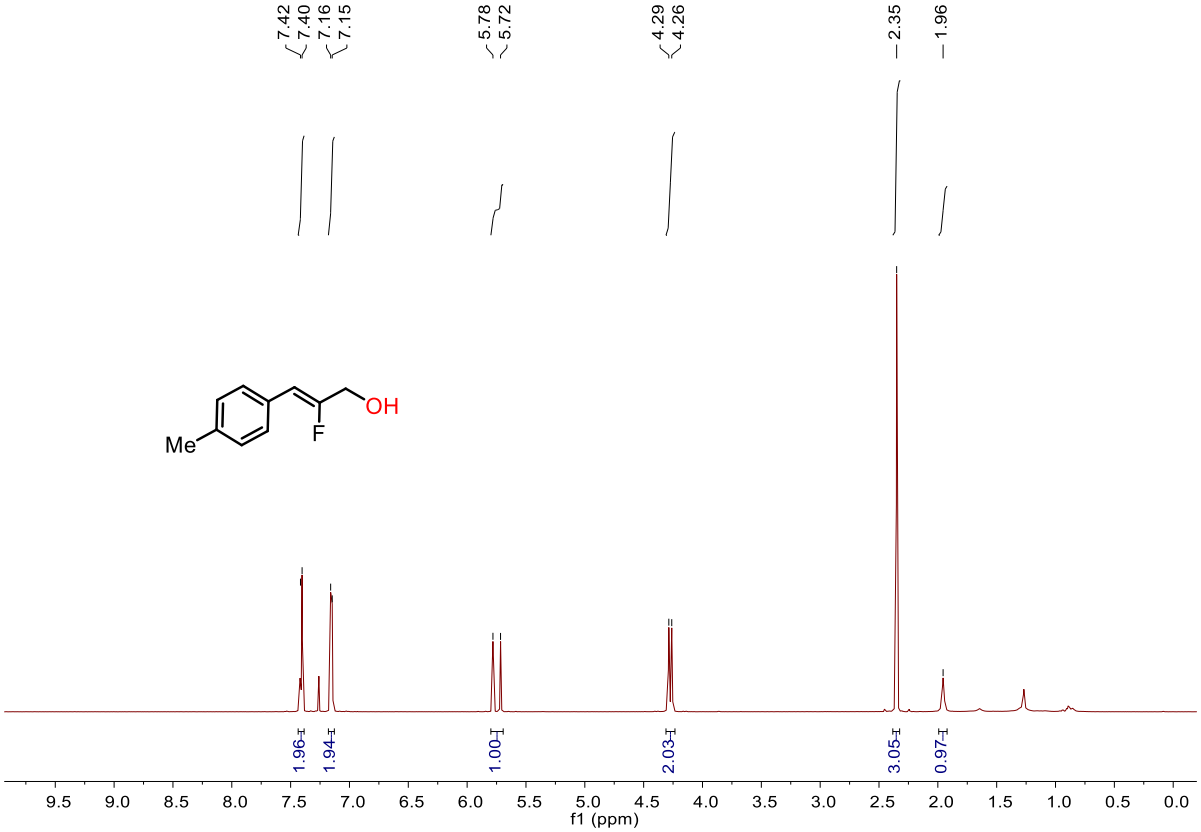
^{19}F NMR (substrate **1zc**)



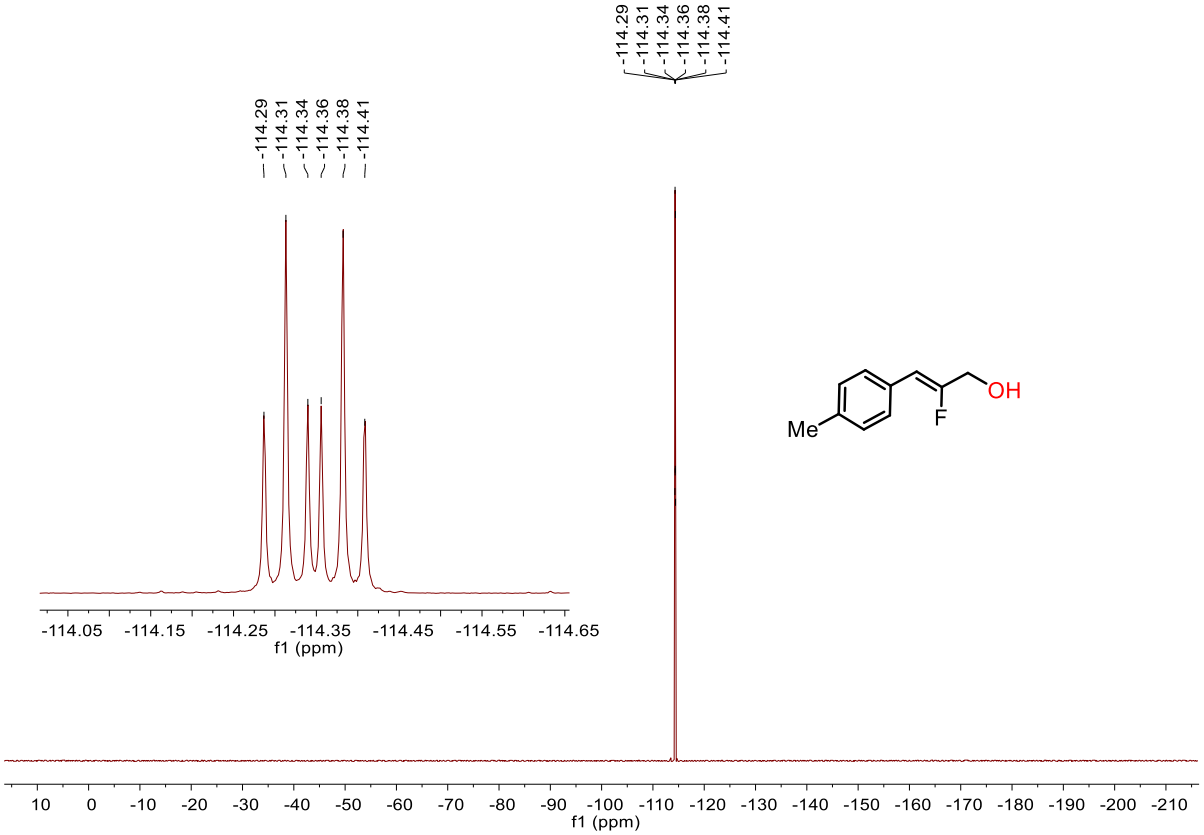
^{13}C NMR (substrate **1zc**)



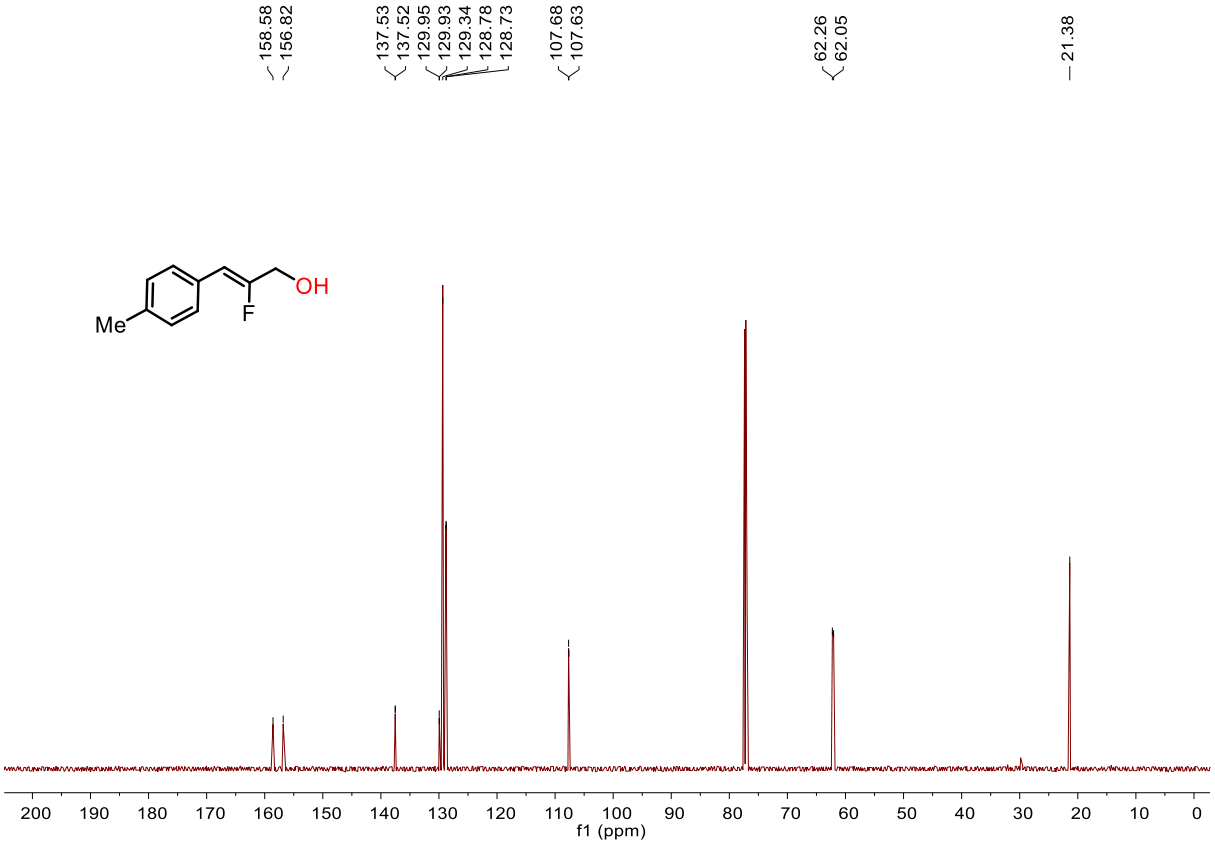
^{1}H NMR (product **2a**)



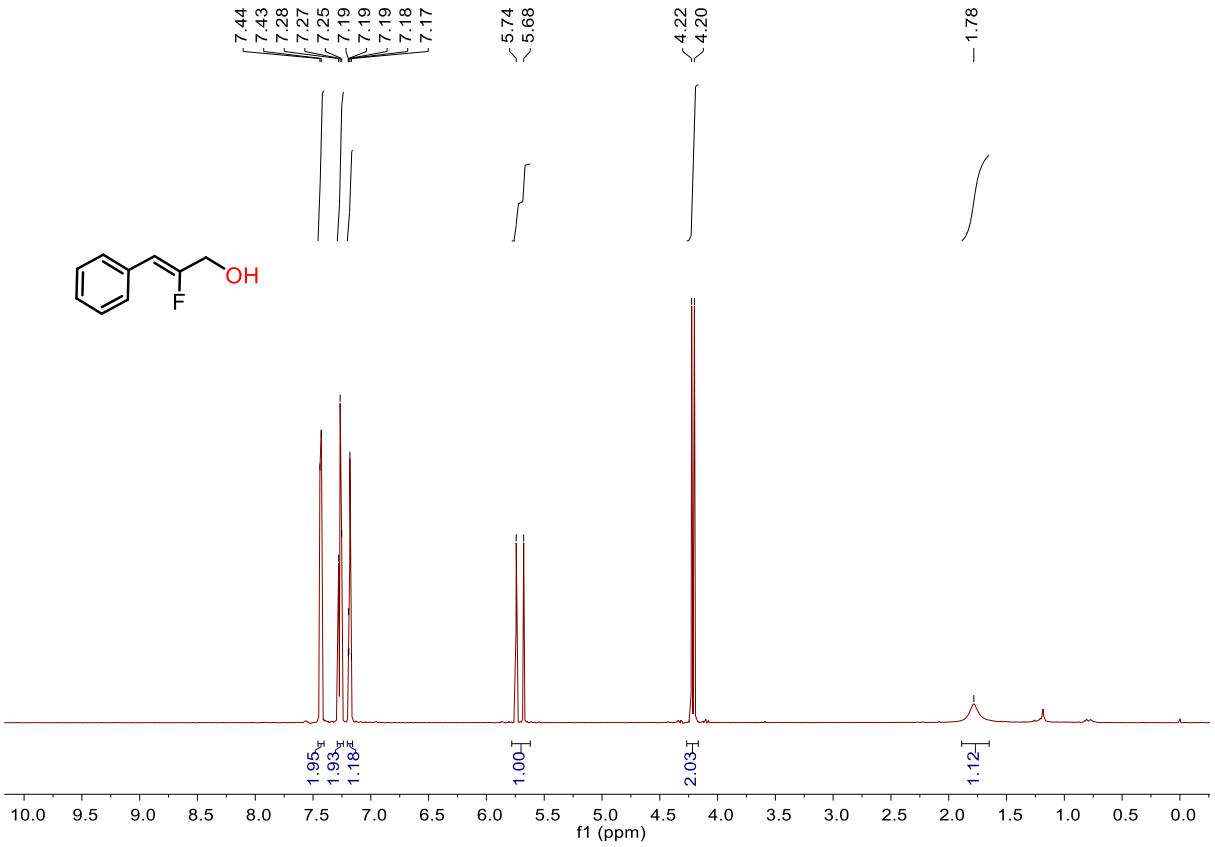
^{19}F NMR (product **2a**)



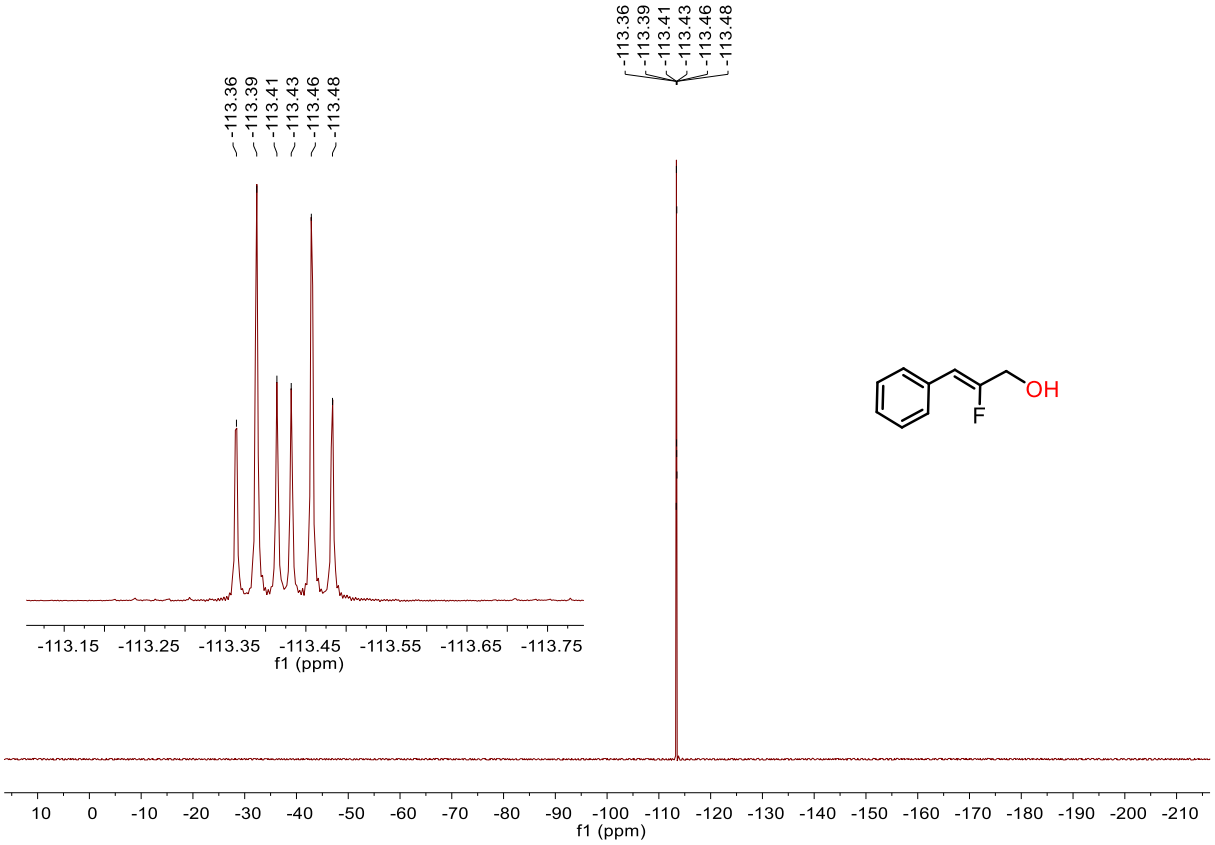
^{13}C NMR (product **2a**)



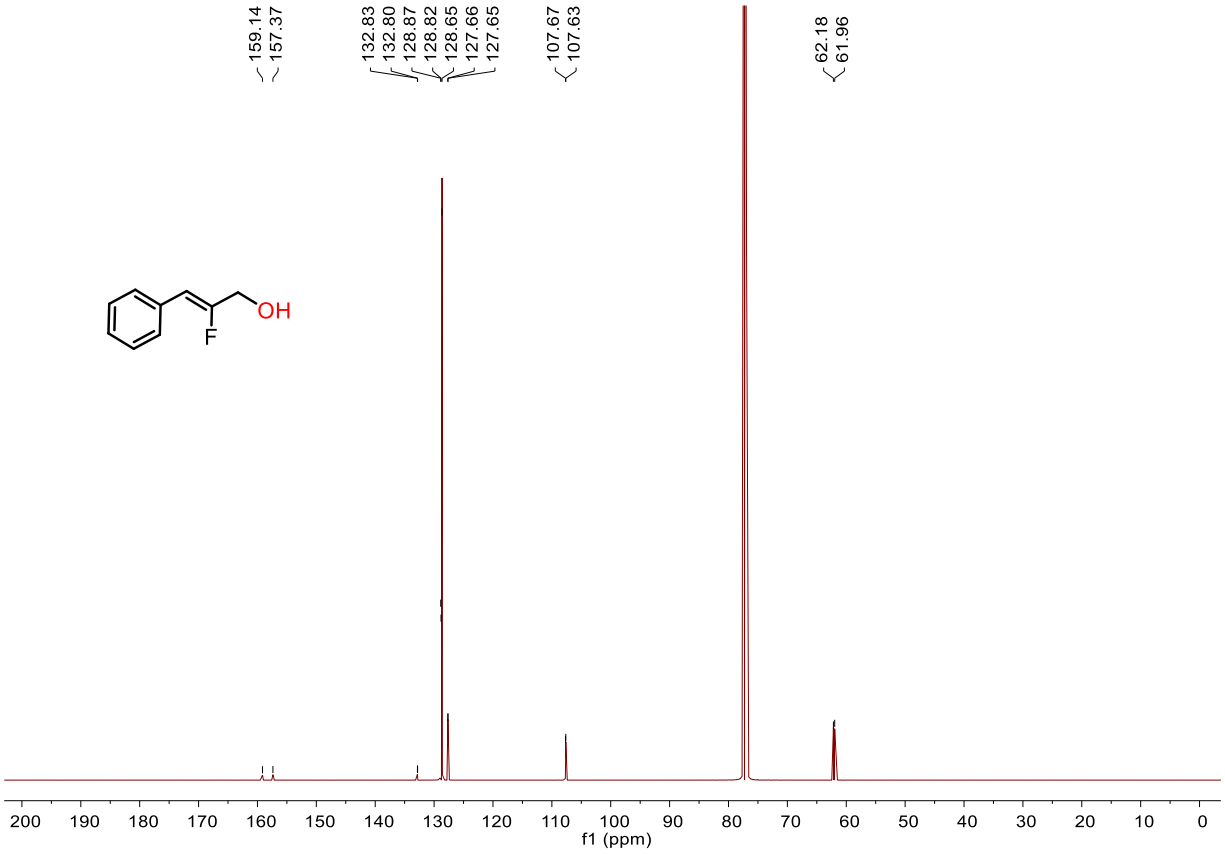
^{1}H NMR (product **2b**)



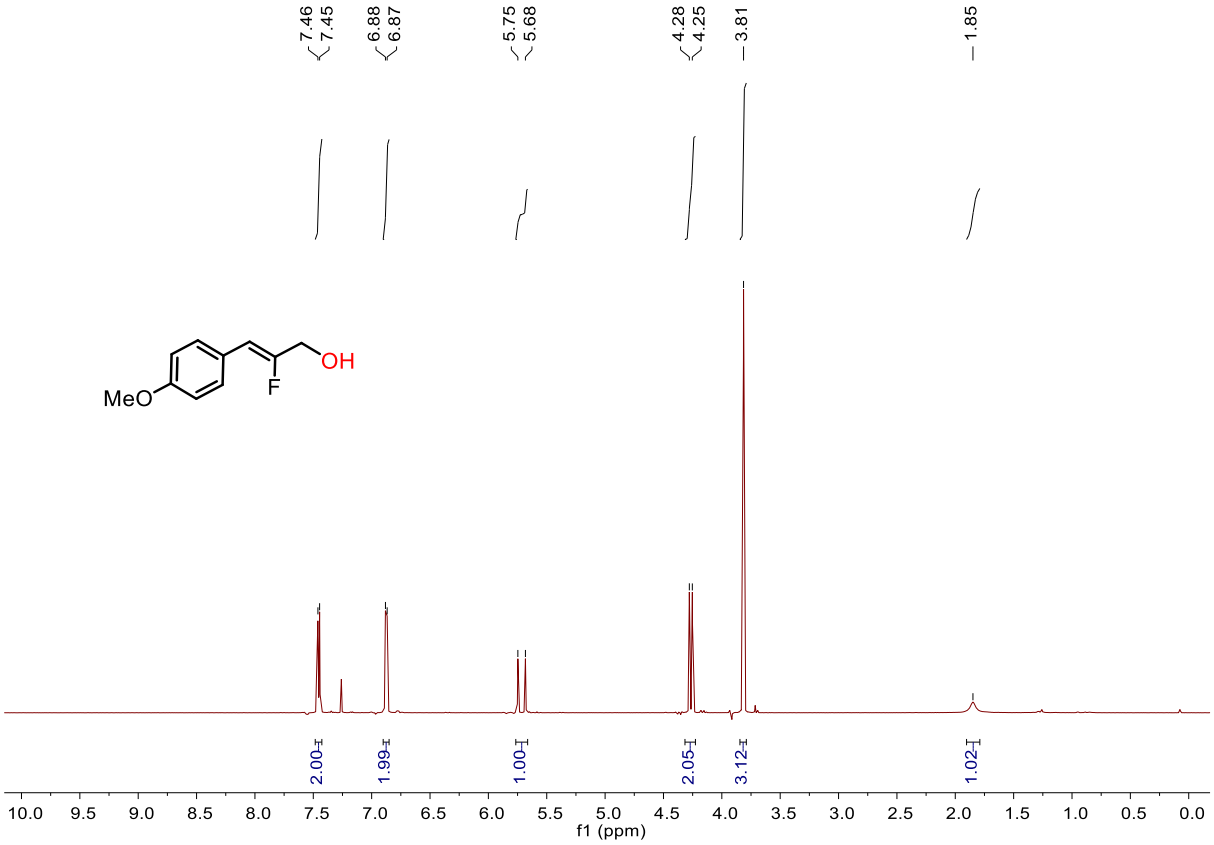
^{19}F NMR (product **2b**)



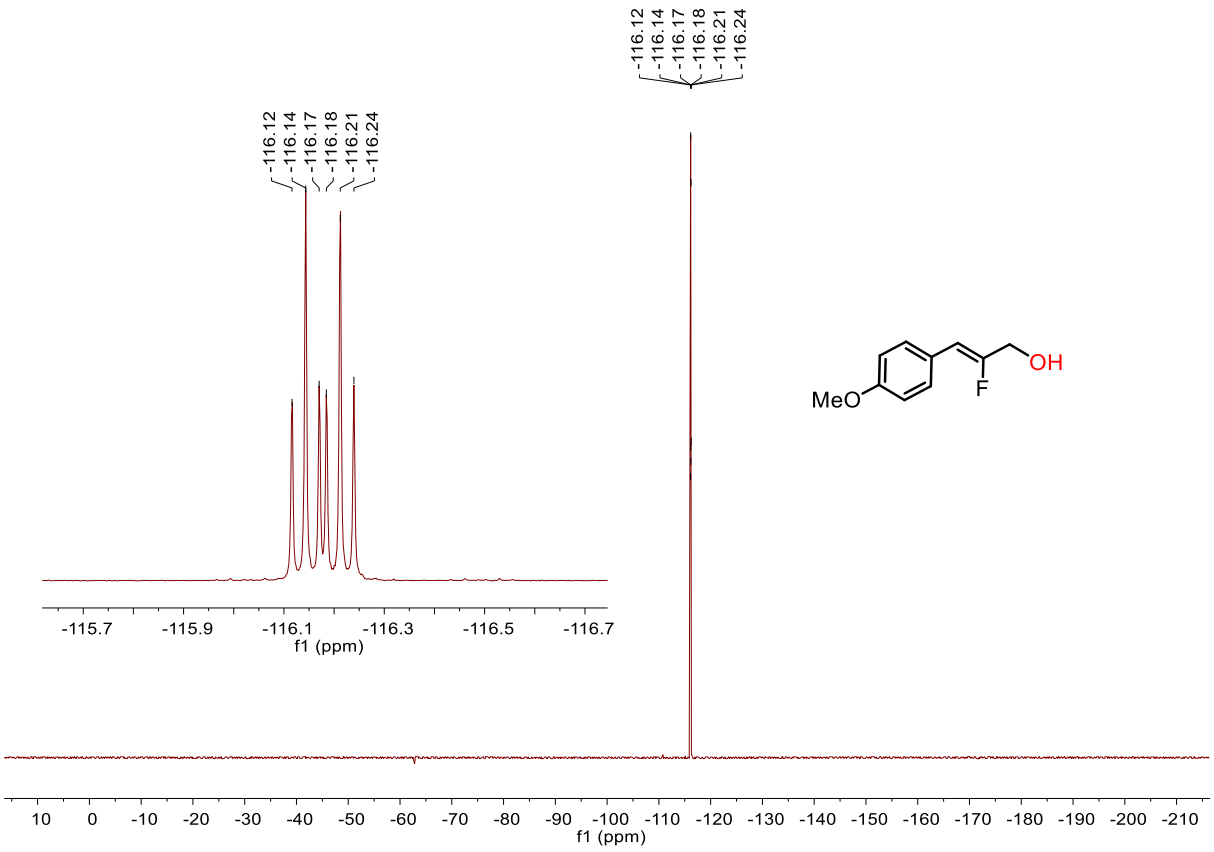
^{13}C NMR (**2b**)



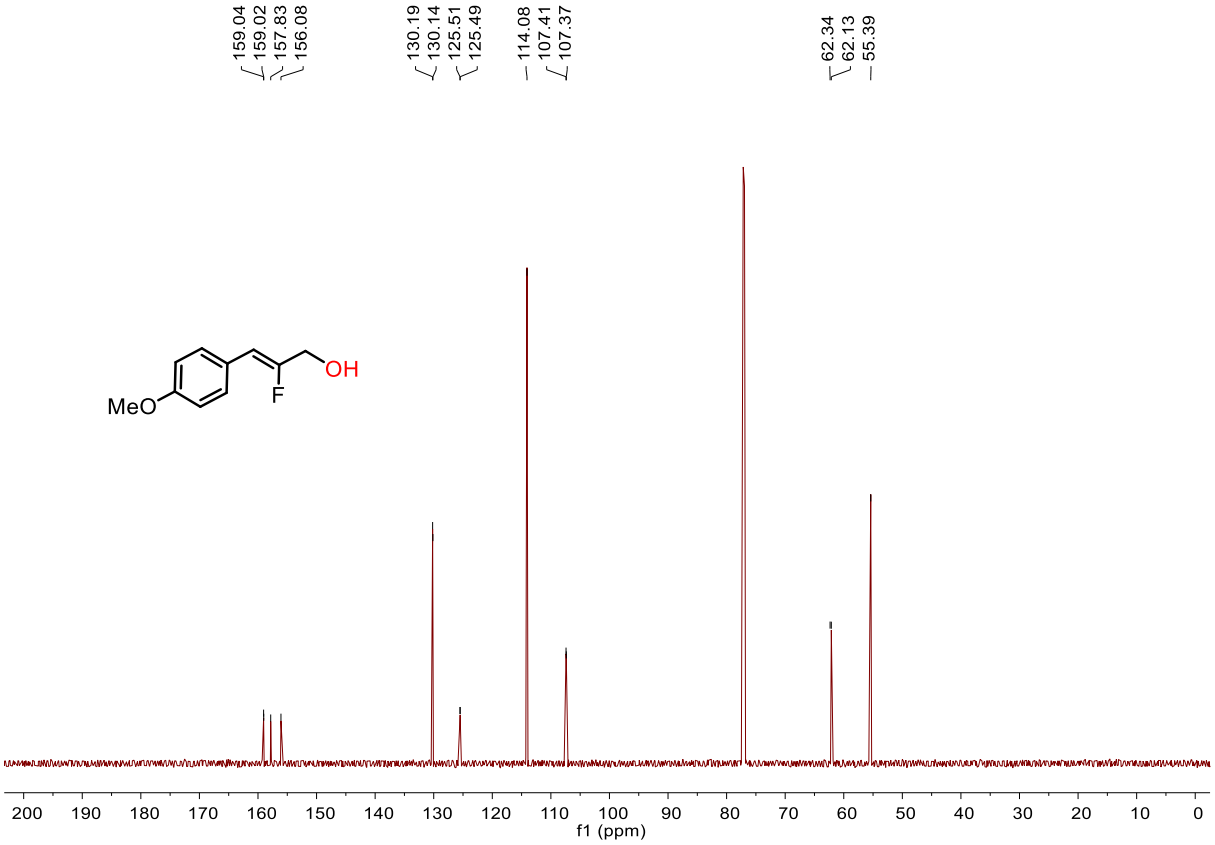
^{1}H NMR (product **2c**)



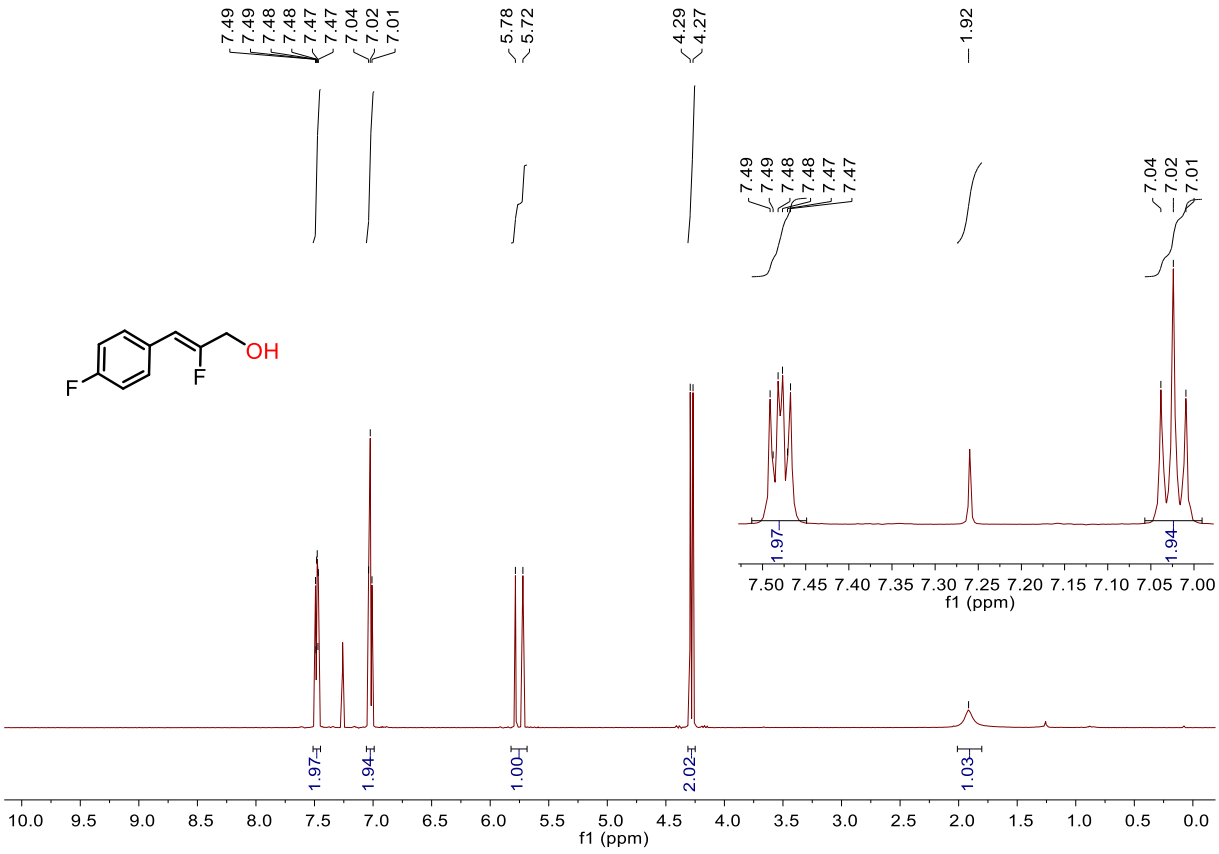
^{19}F NMR (product **2c**)



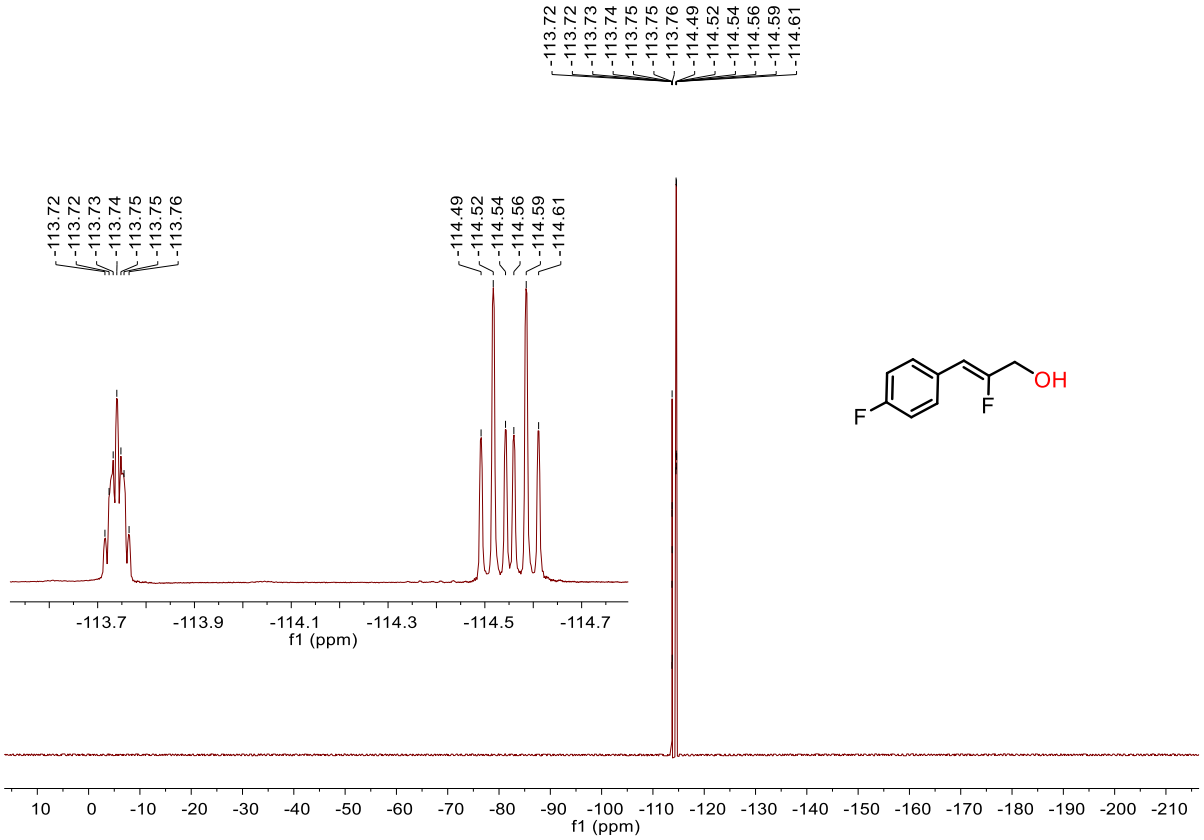
^{13}C NMR (product **2c**)



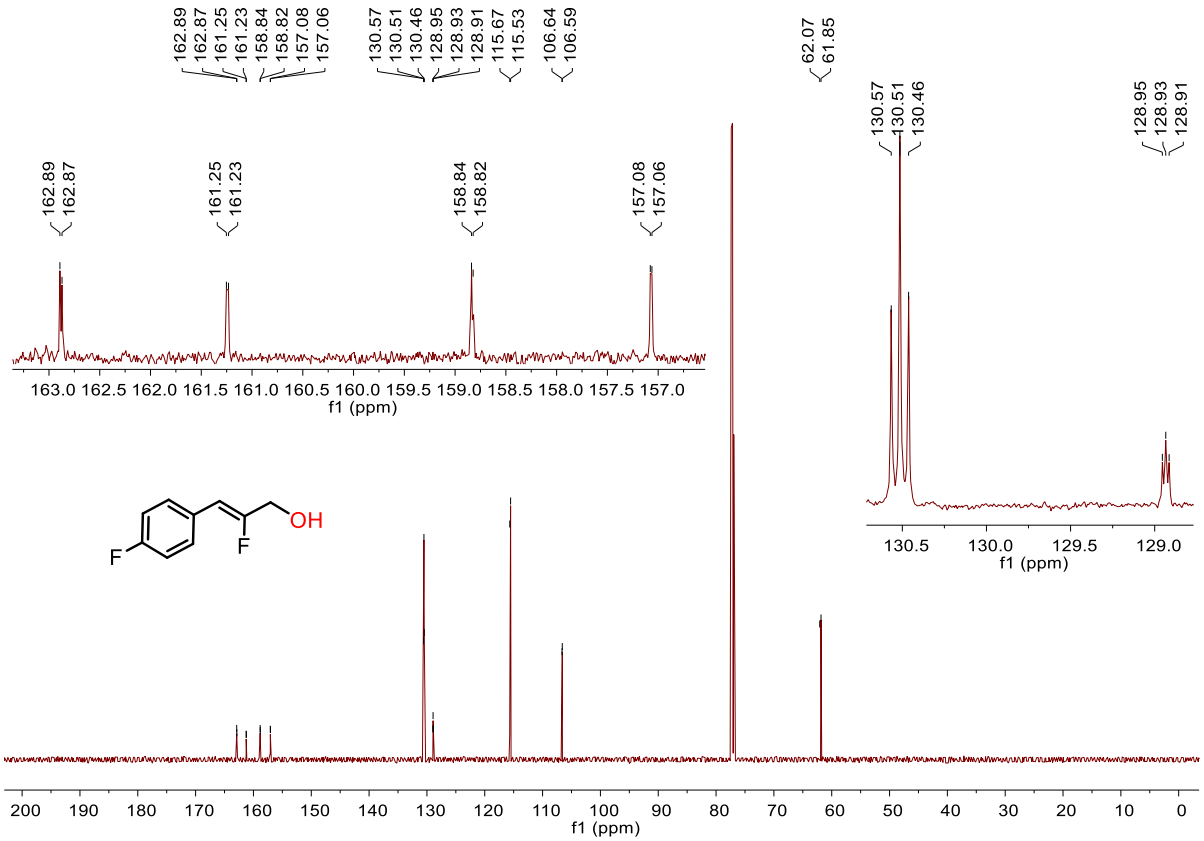
^{1}H NMR (product **2d**)



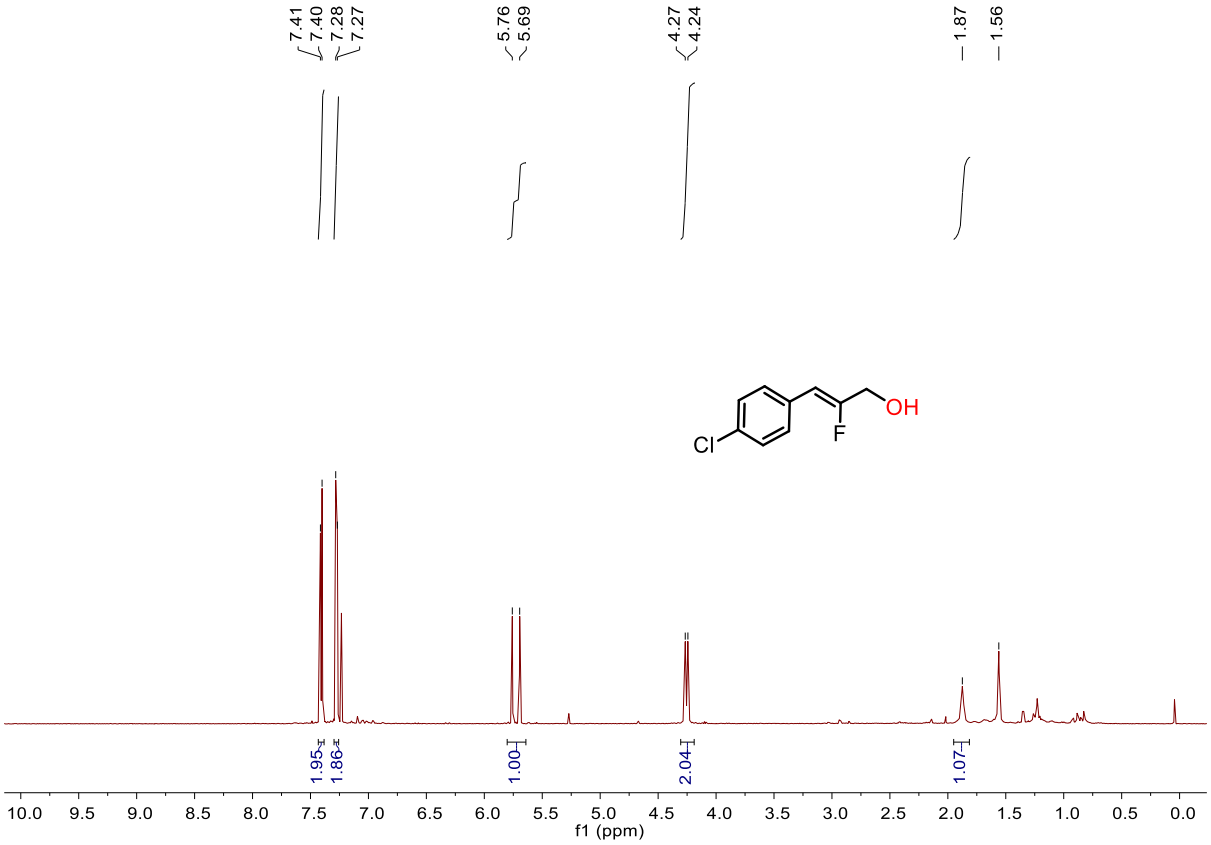
^{19}F NMR (product **2d**)



^{13}C NMR (product **2d**)

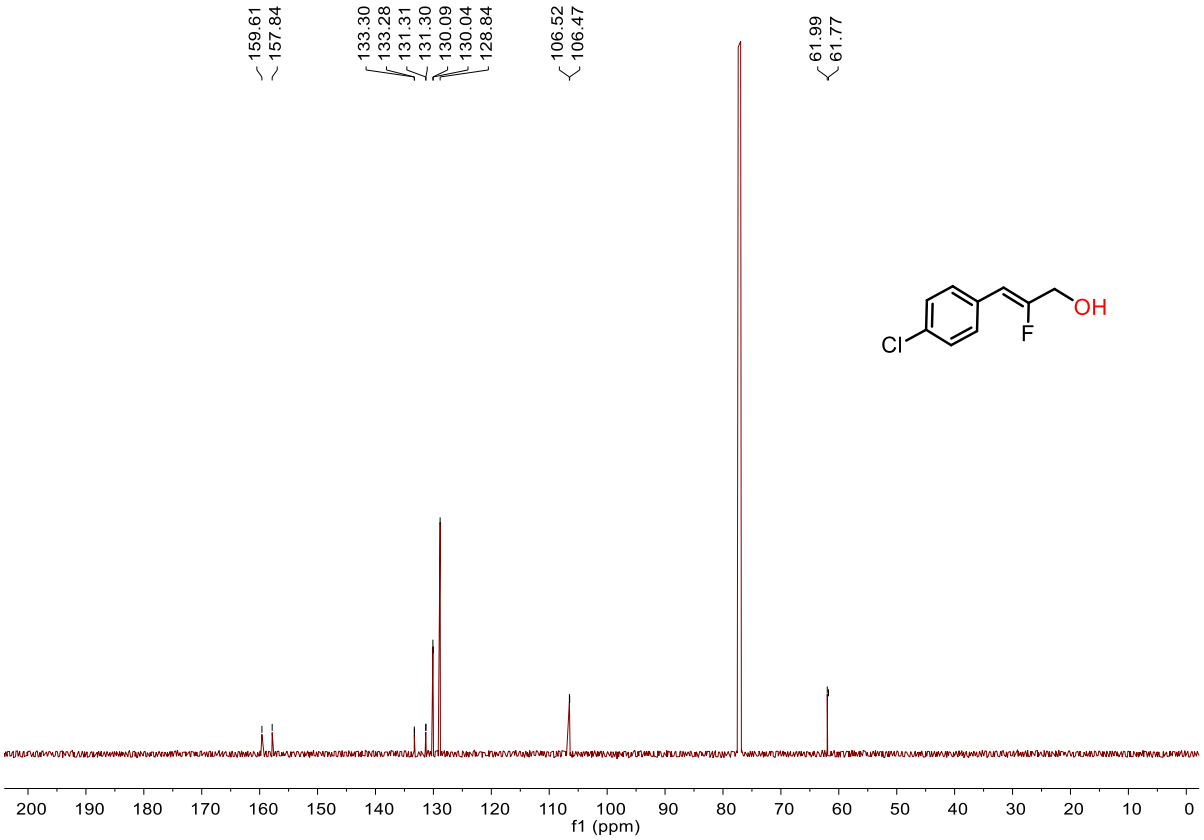


^{1}H NMR (product **2e**)

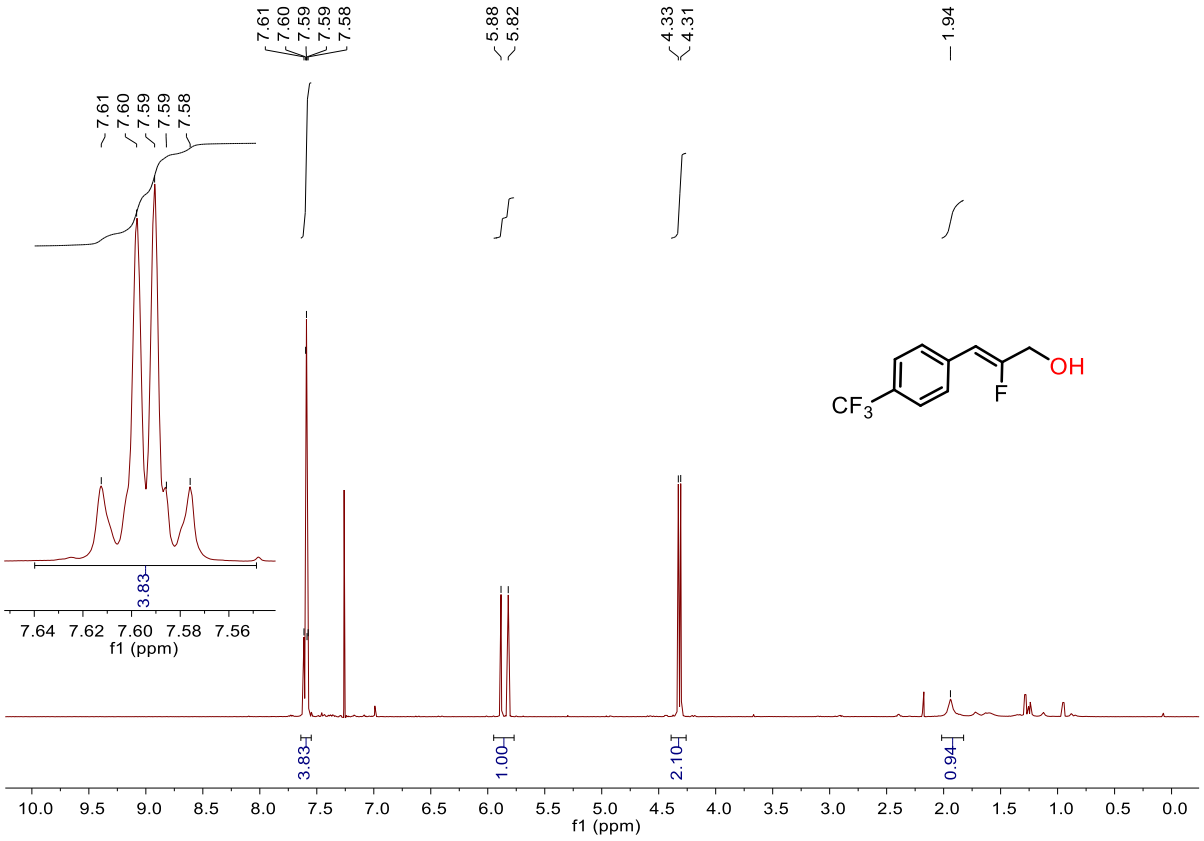


^{19}F NMR (product **2e**)

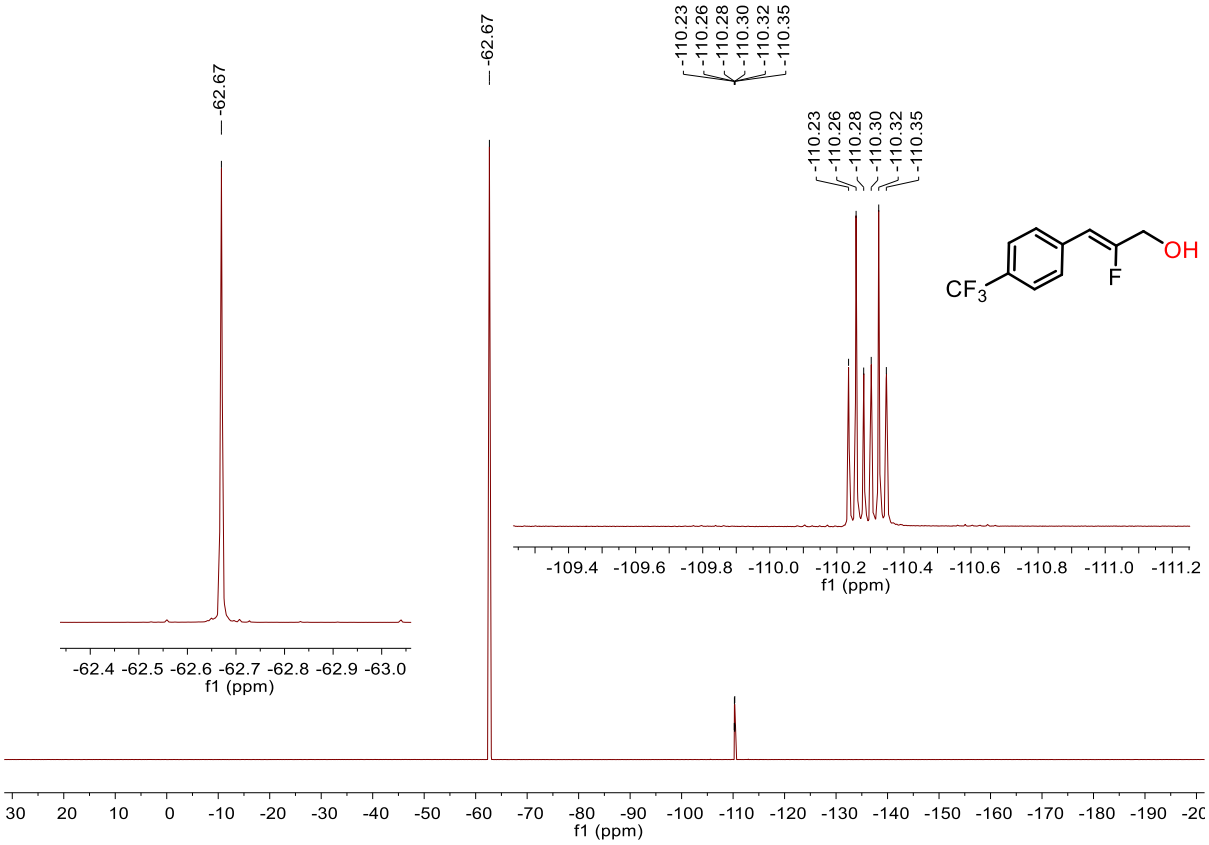
^{13}C NMR (product **2e**)



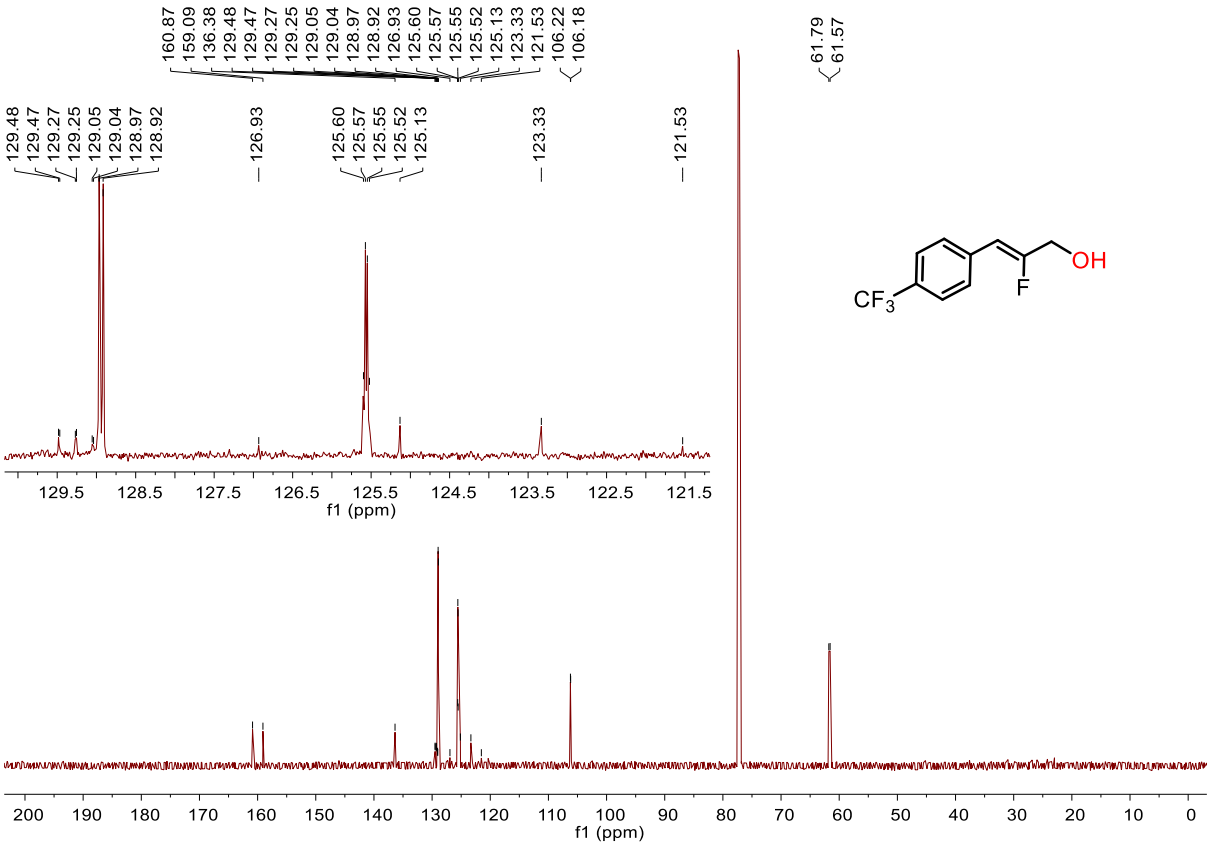
^{1}H NMR (product **2f**)



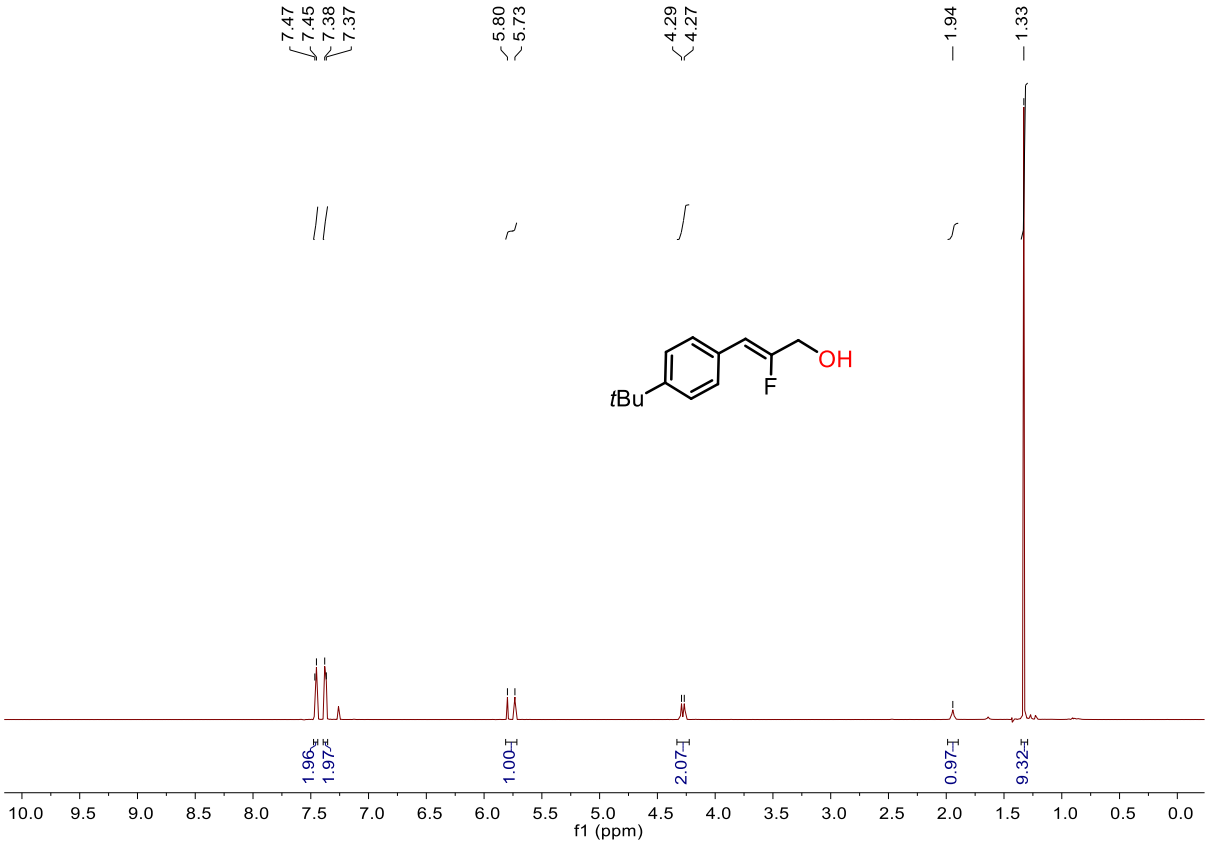
^{19}F NMR (product **2f**)



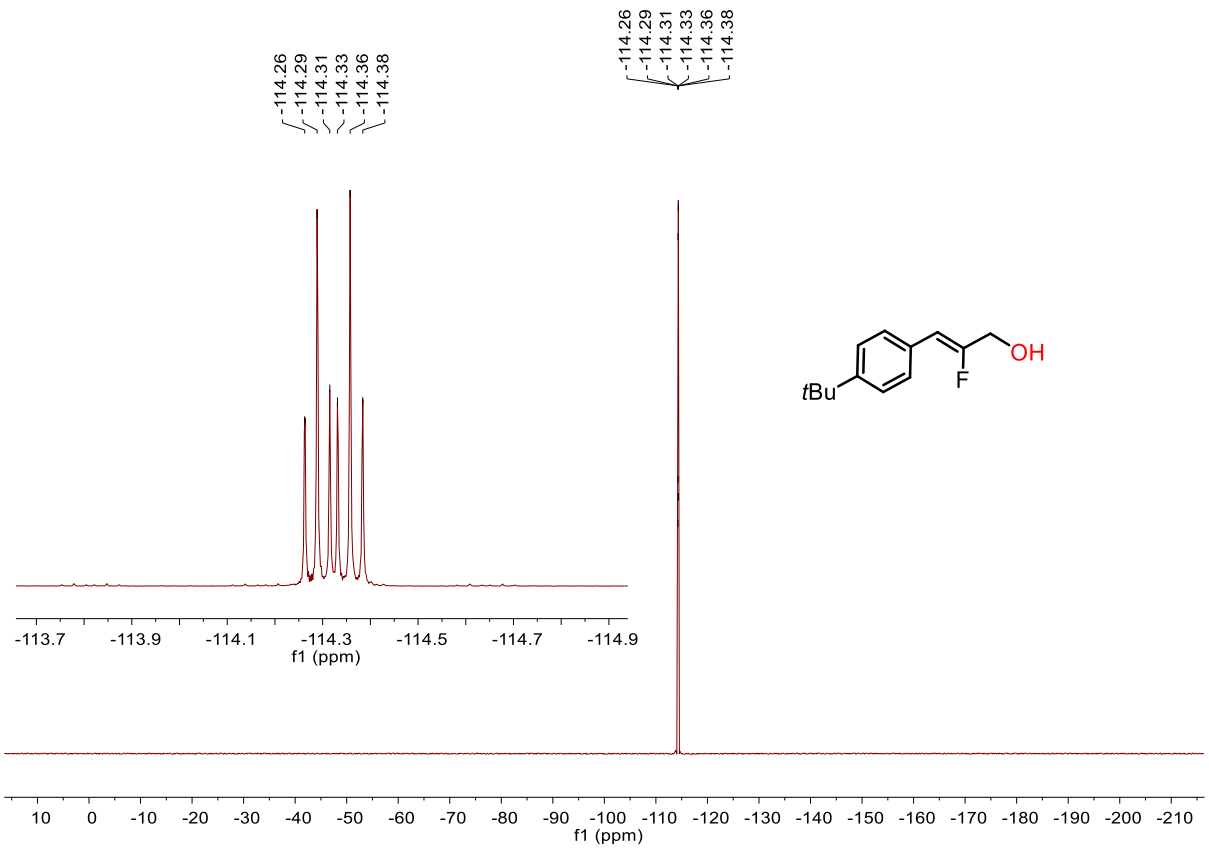
^{13}C NMR (product **2f**)



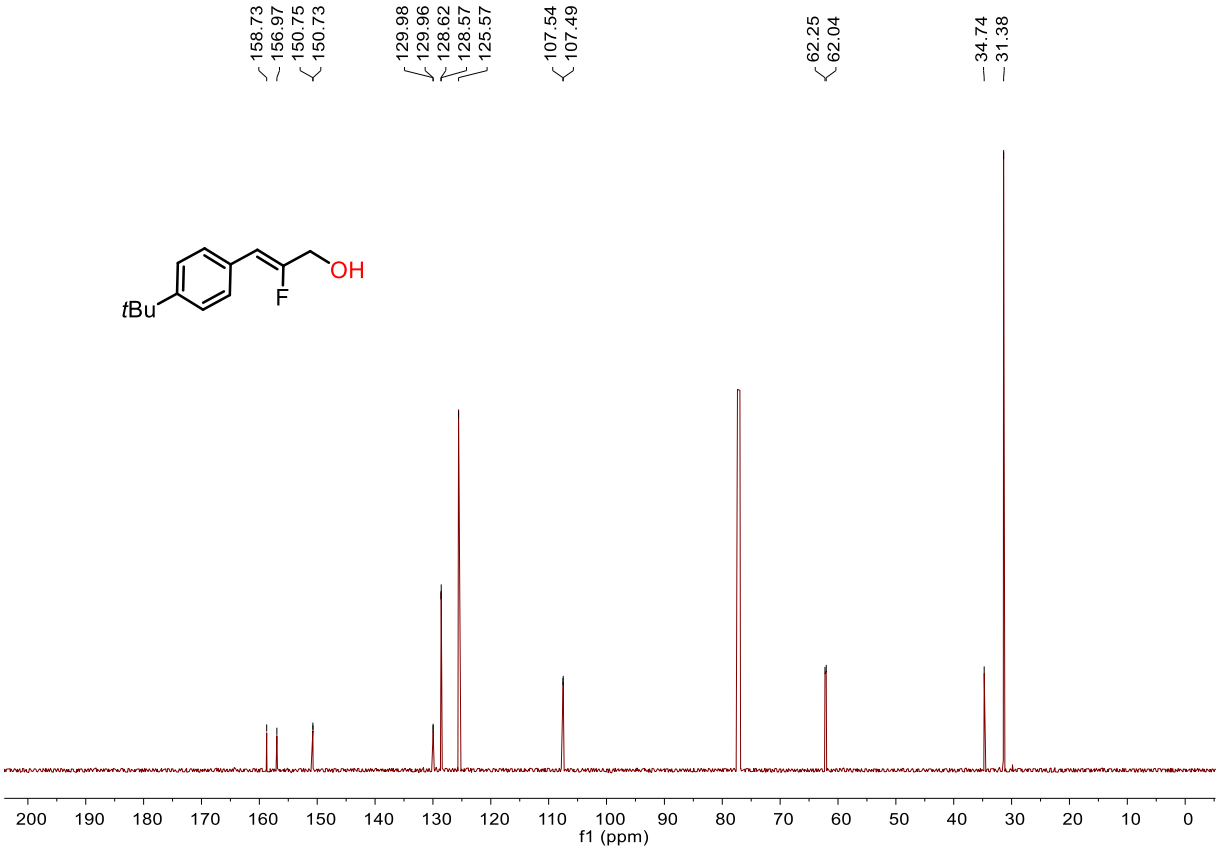
^{1}H NMR (product **2g**)



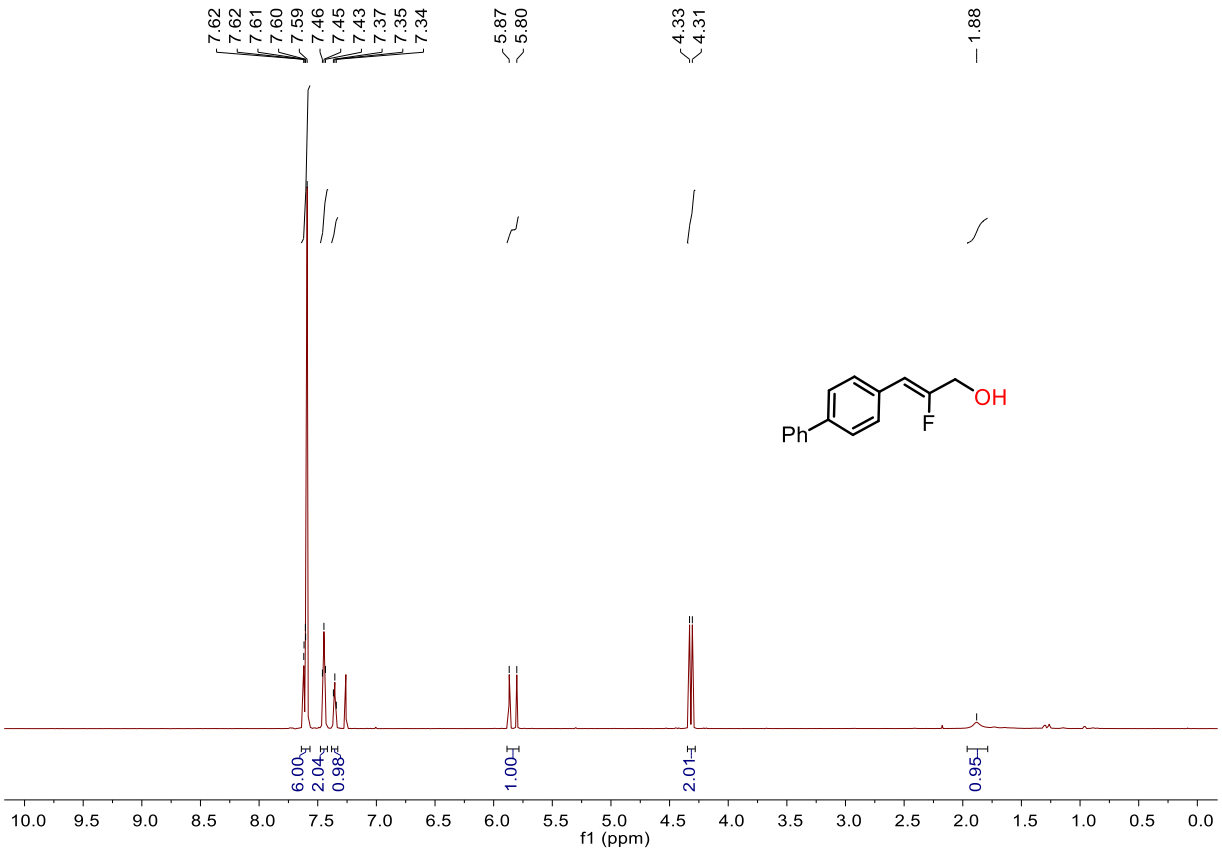
^{19}F NMR (product **2g**)



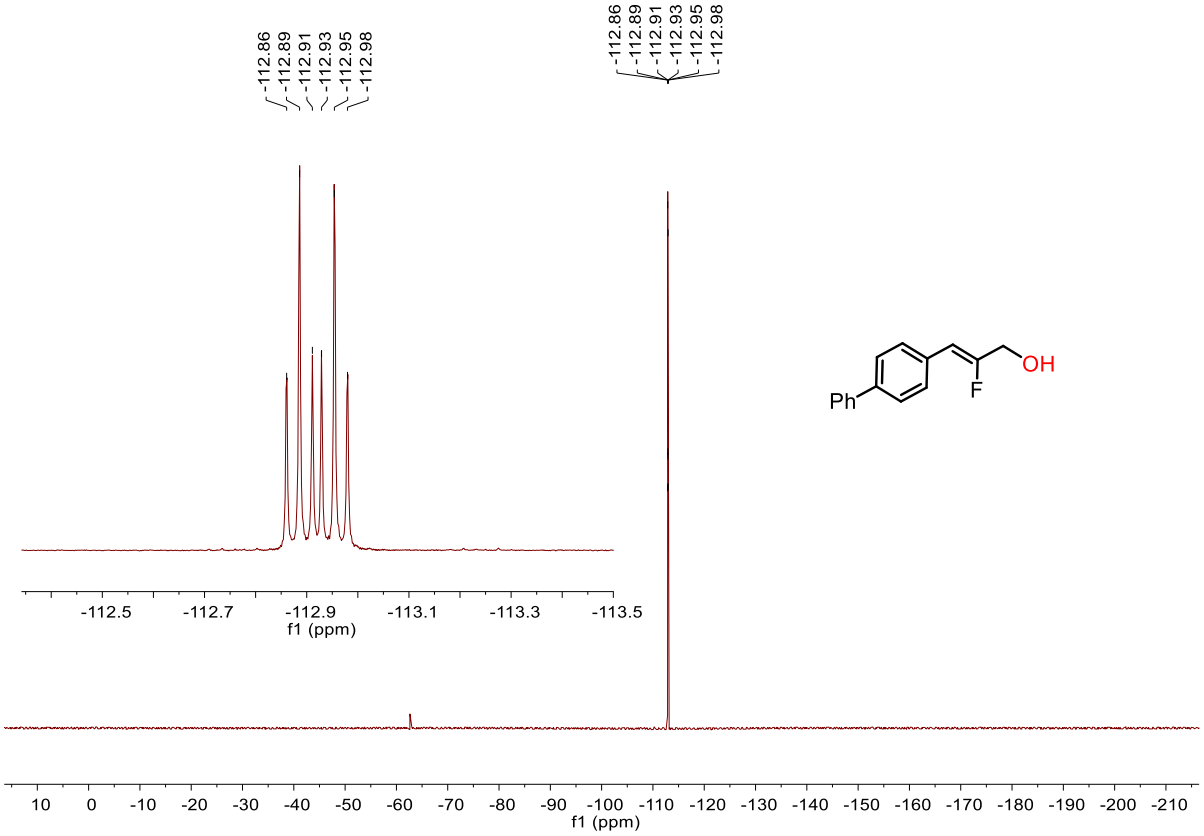
^{13}C NMR (product **2g**)



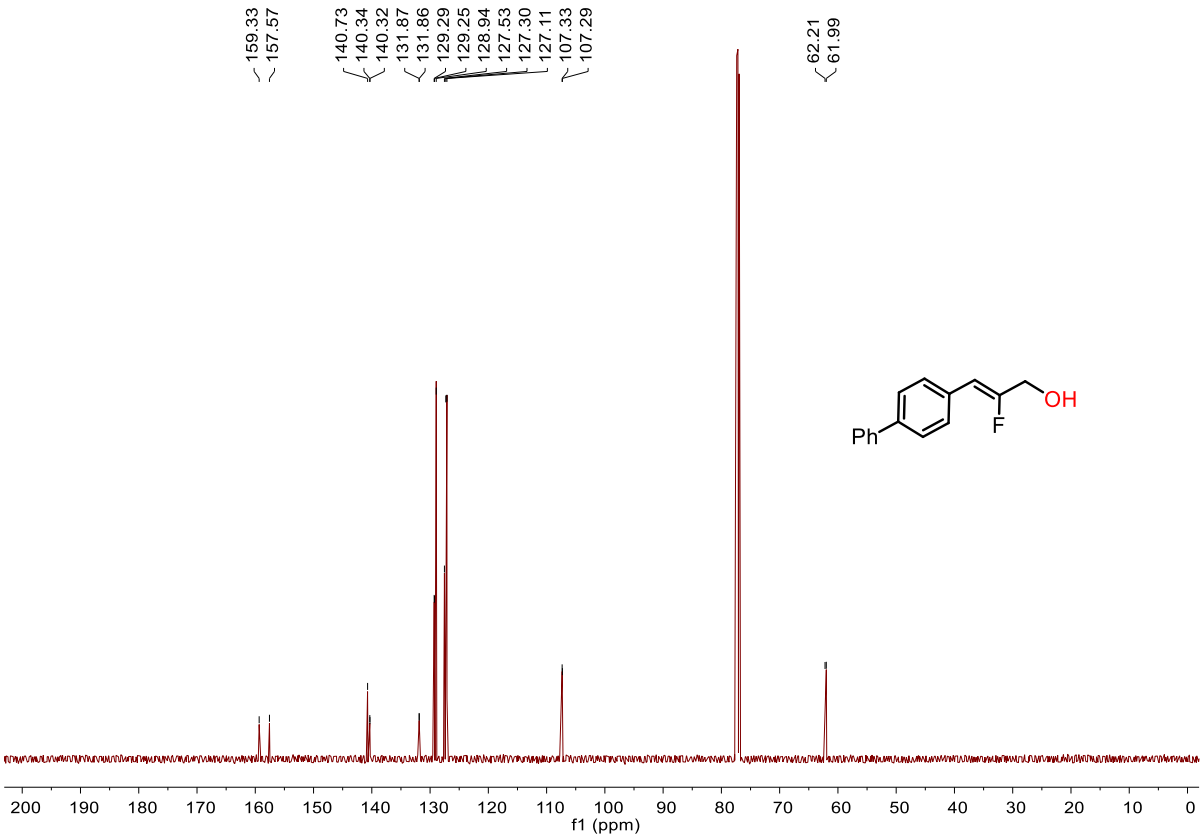
^{1}H NMR (product **2h**)



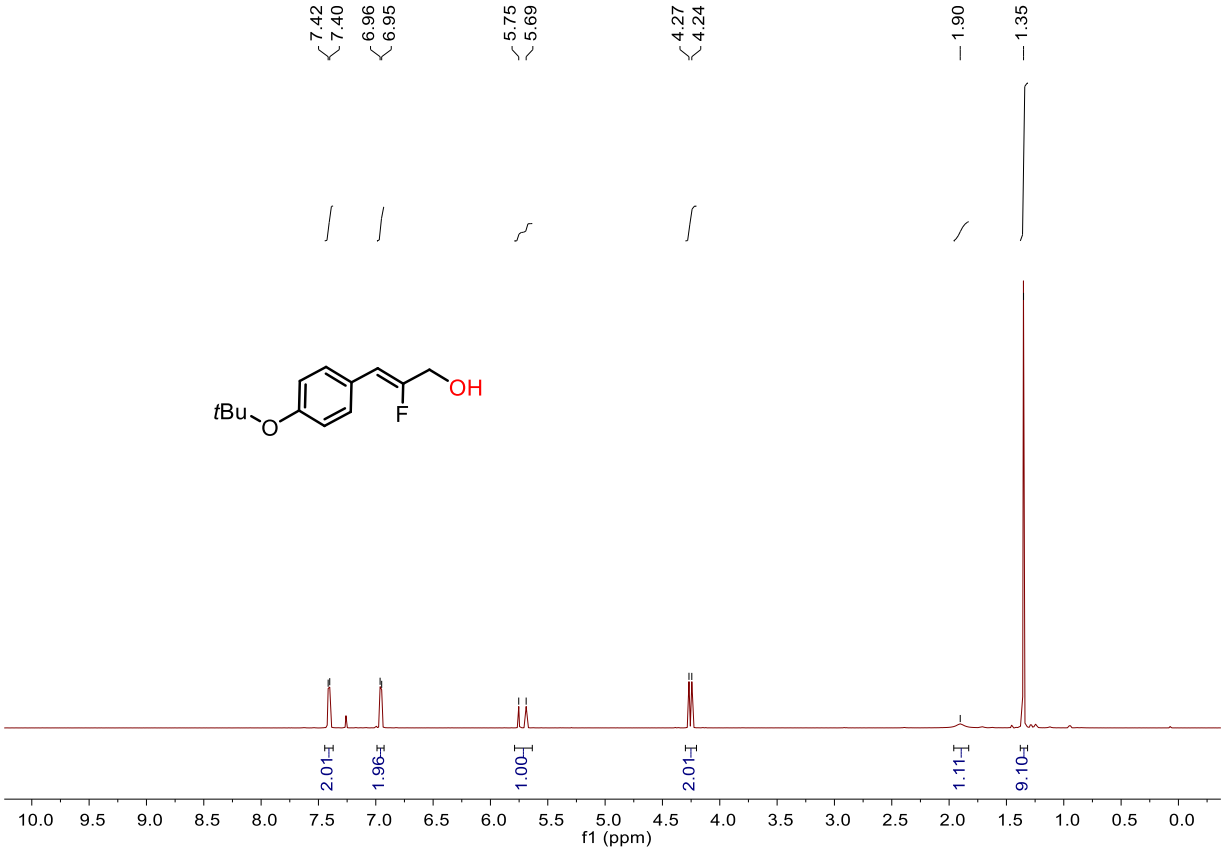
^{19}F NMR (product **2h**)



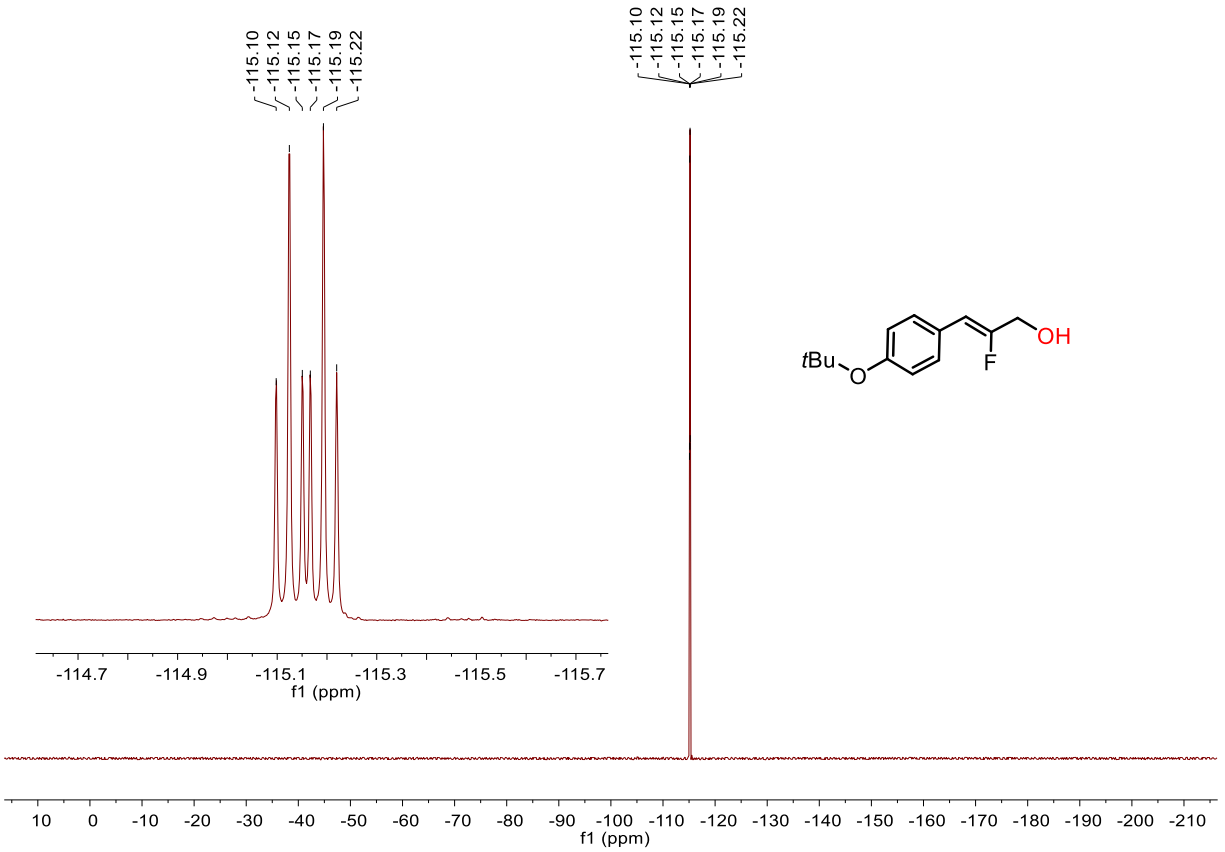
^{13}C NMR (product **2h**)



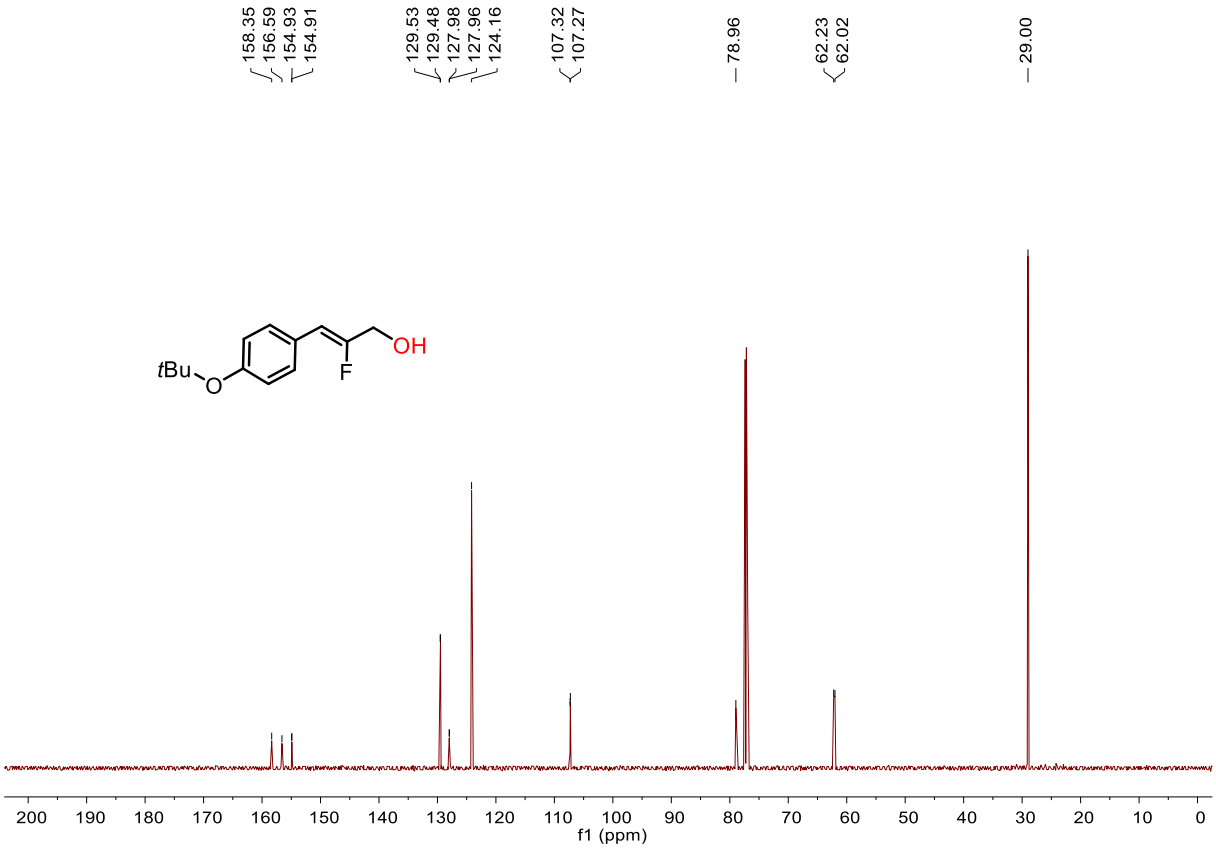
^{1}H NMR (product **2i**)



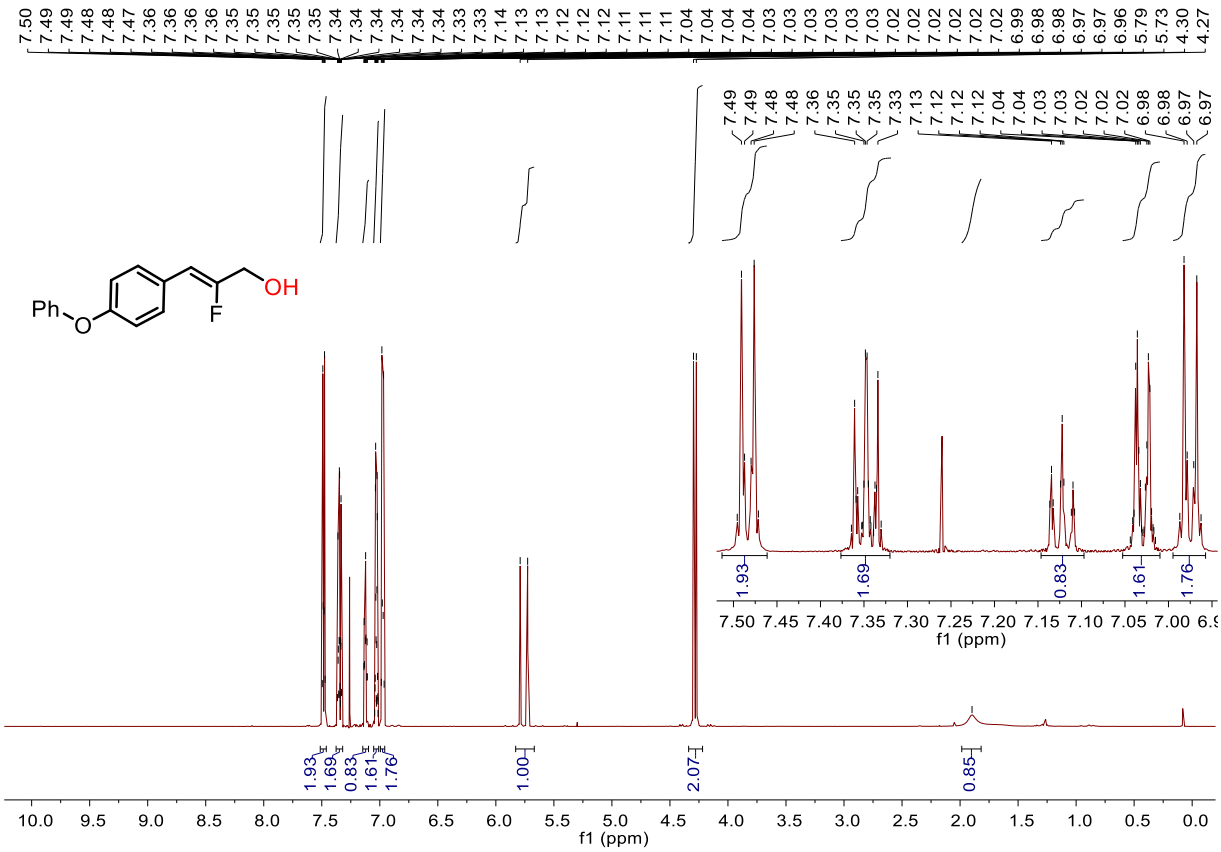
^{19}F NMR (product **2i**)



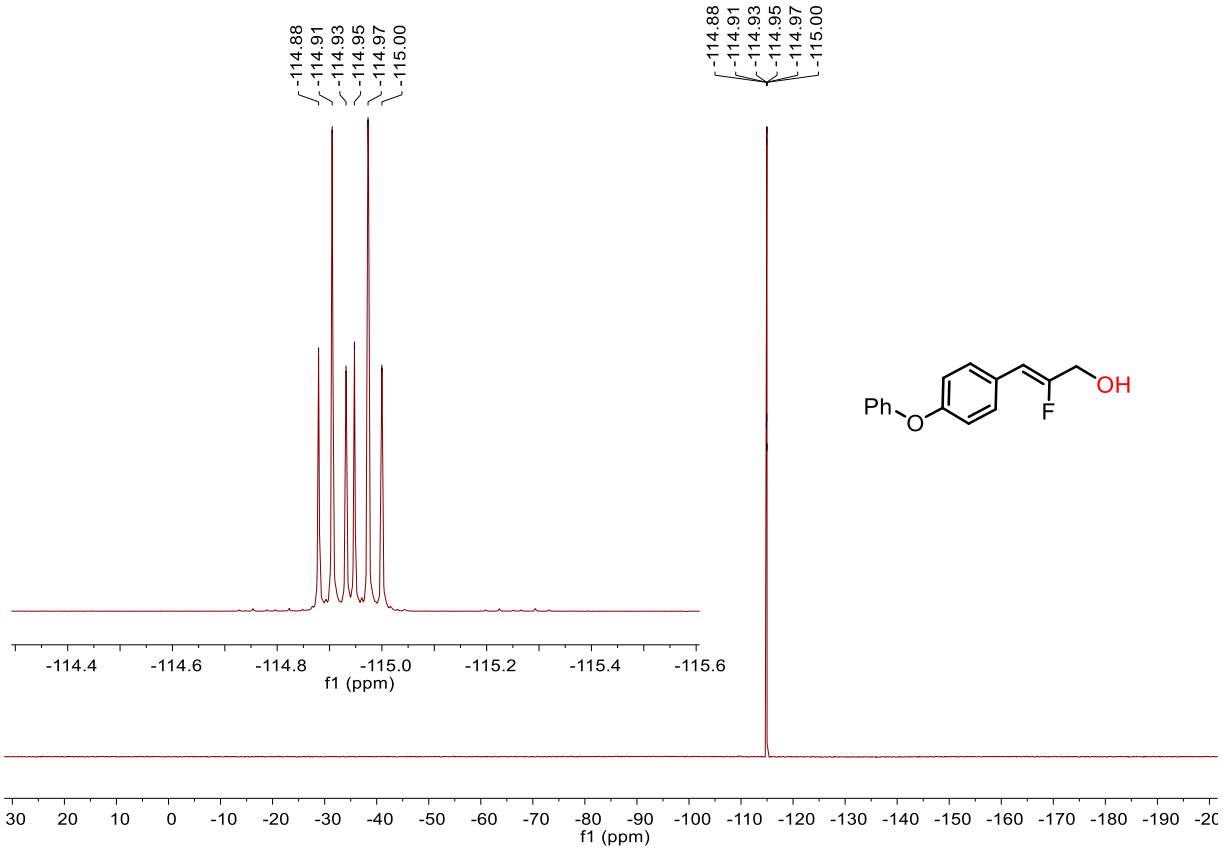
^{13}C NMR (product **2i**)



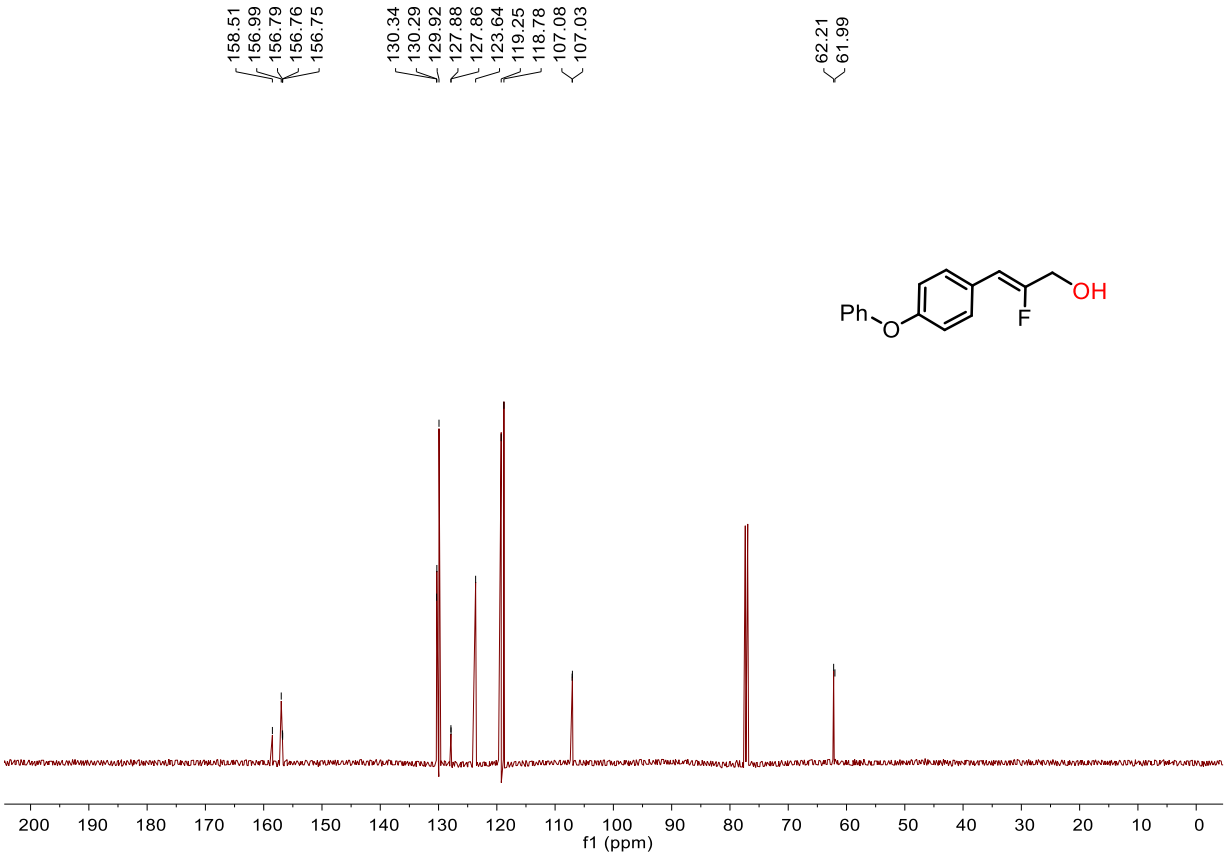
^{1}H NMR (product **2j**)



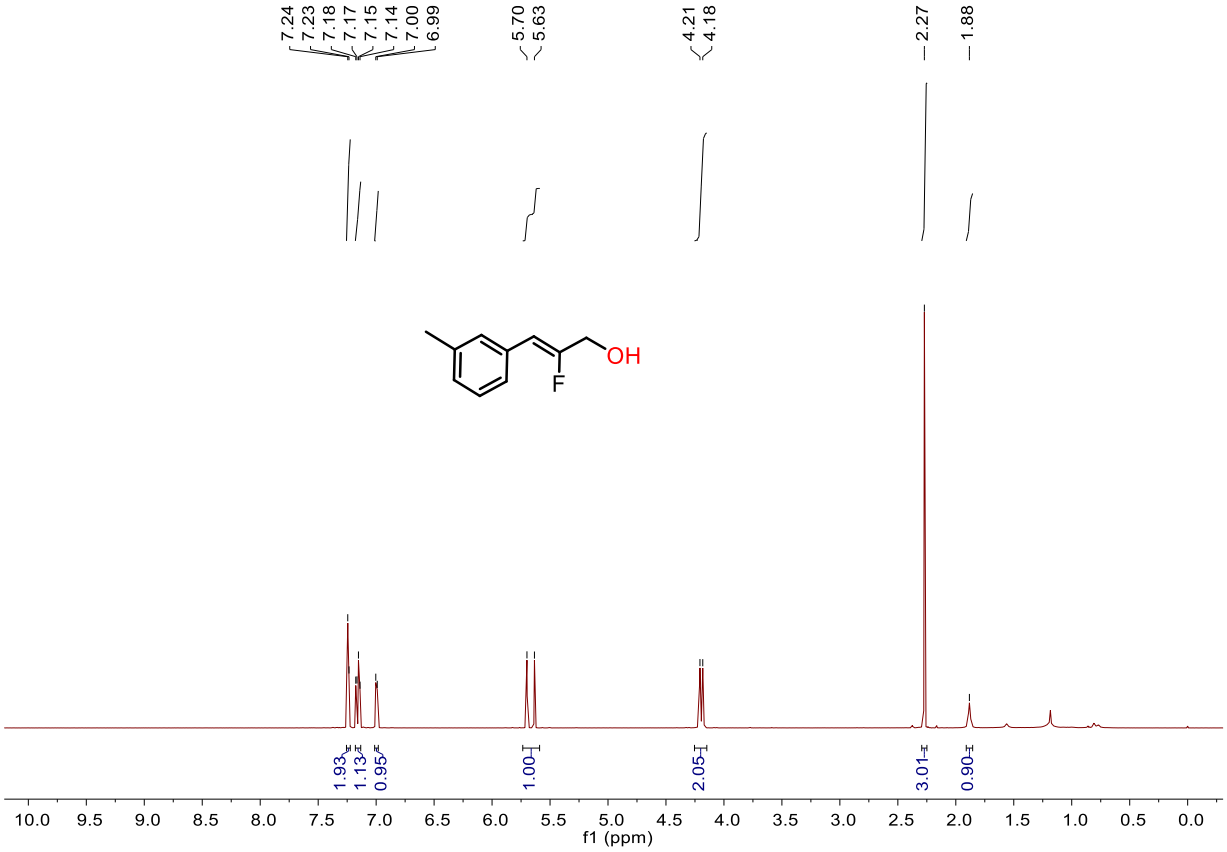
^{19}F NMR (product **2j**)



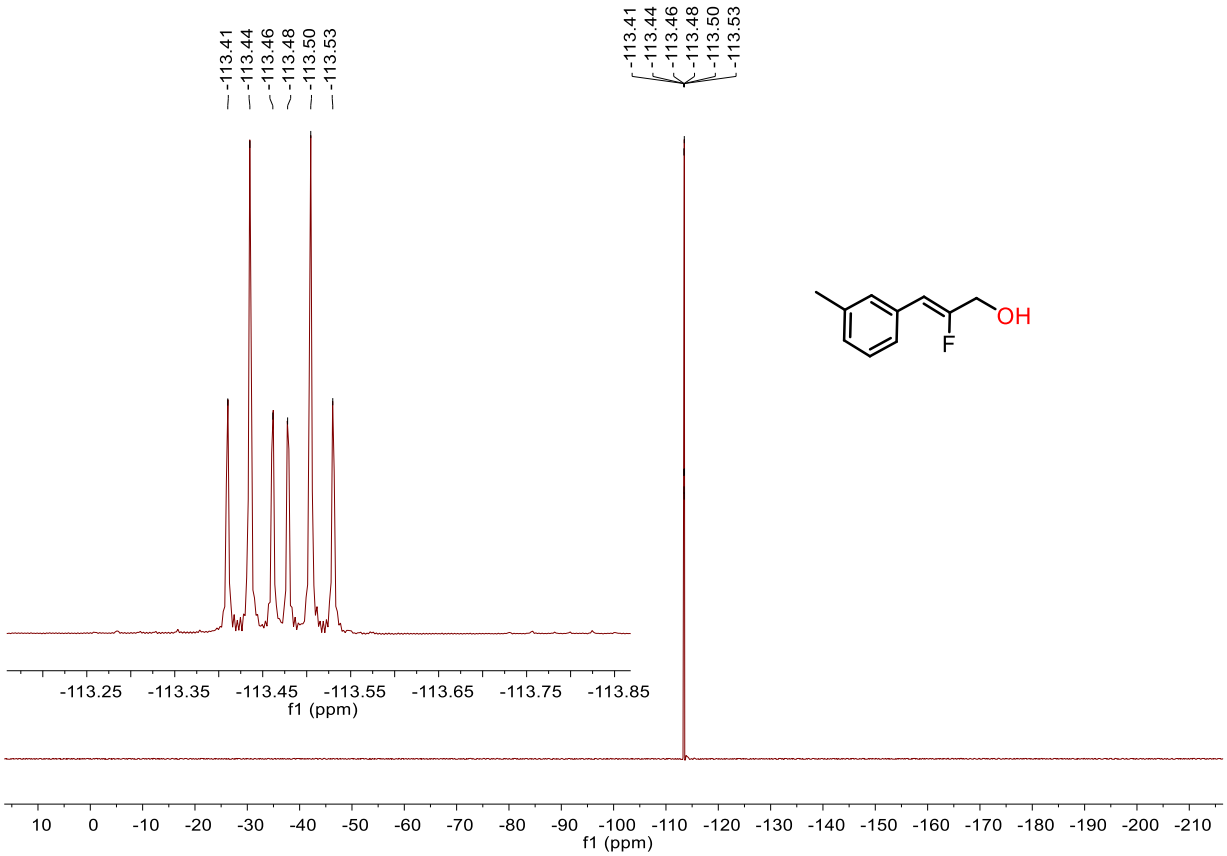
^{13}C NMR (product **2j**)



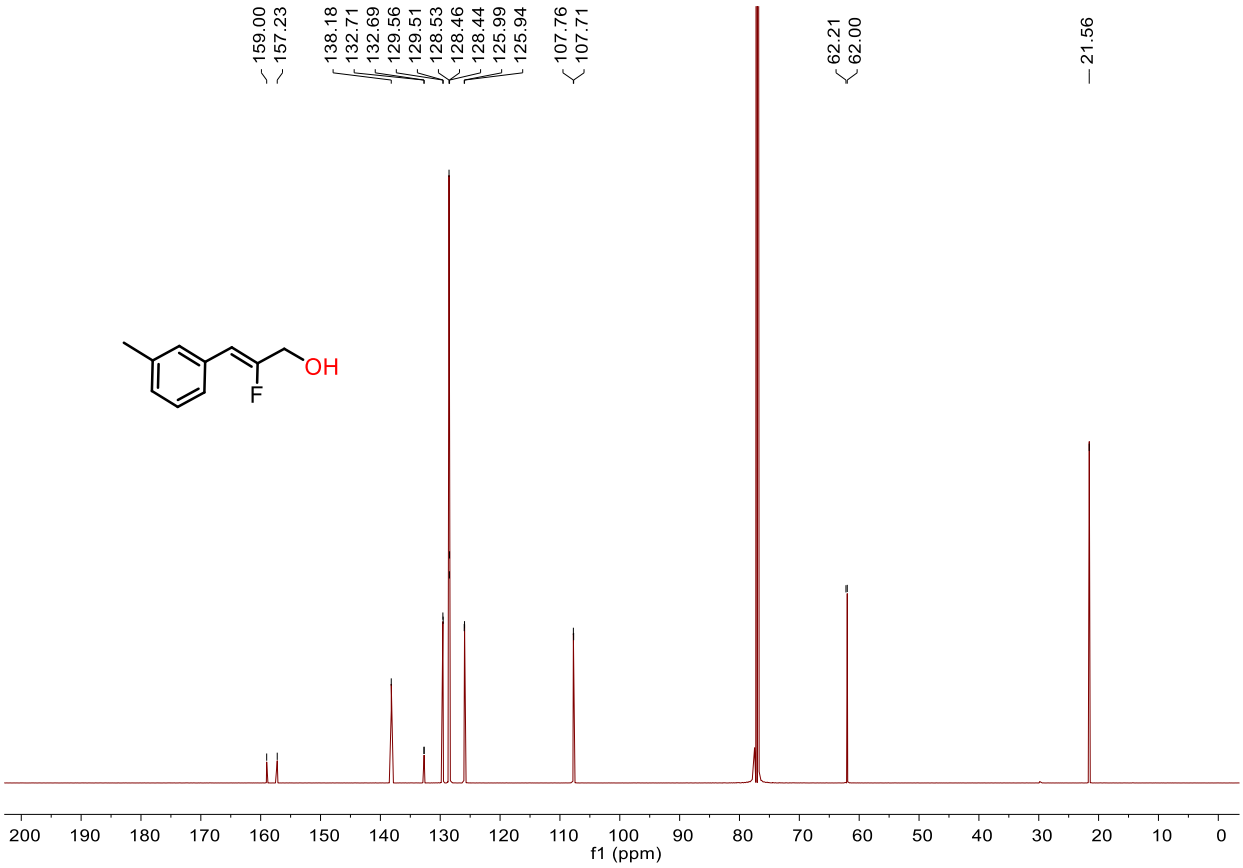
^{1}H NMR (product **2k**)



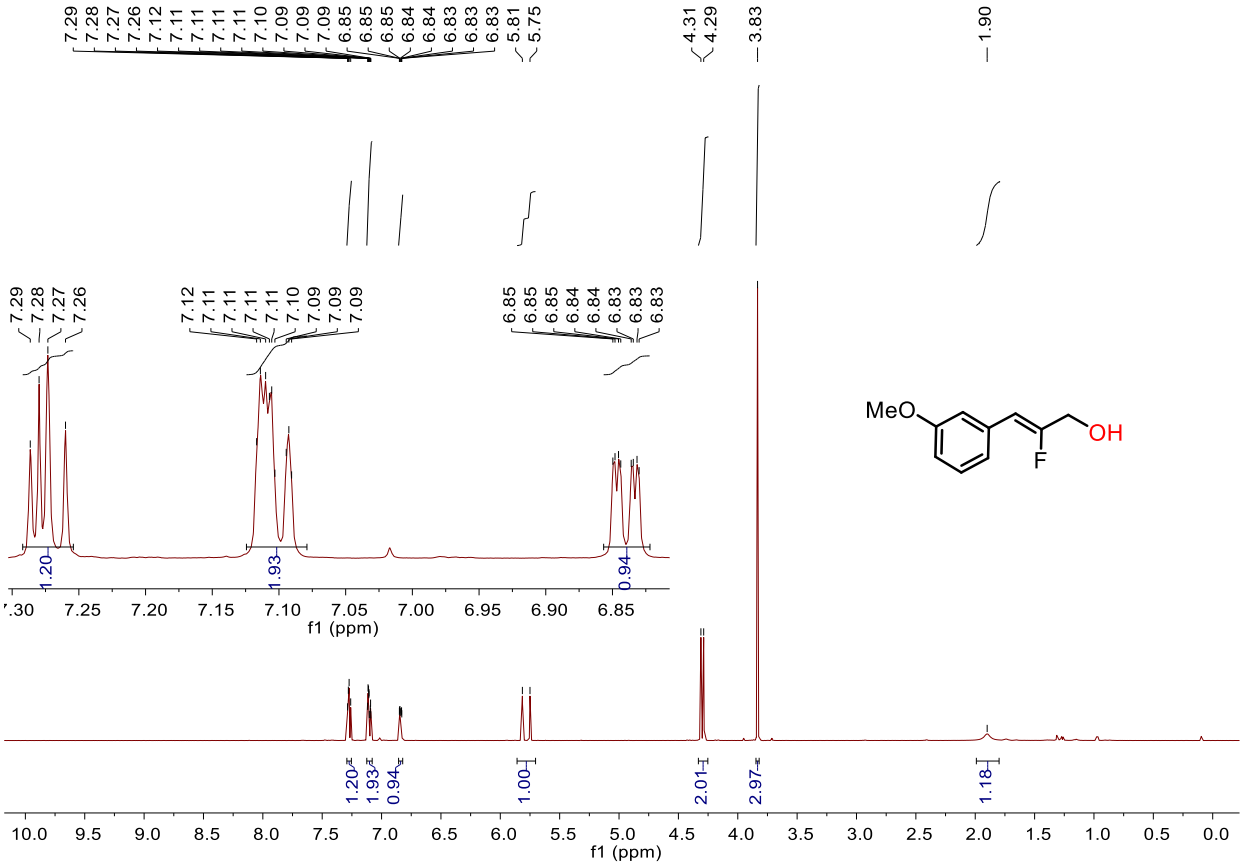
^{19}F NMR (product **2k**)



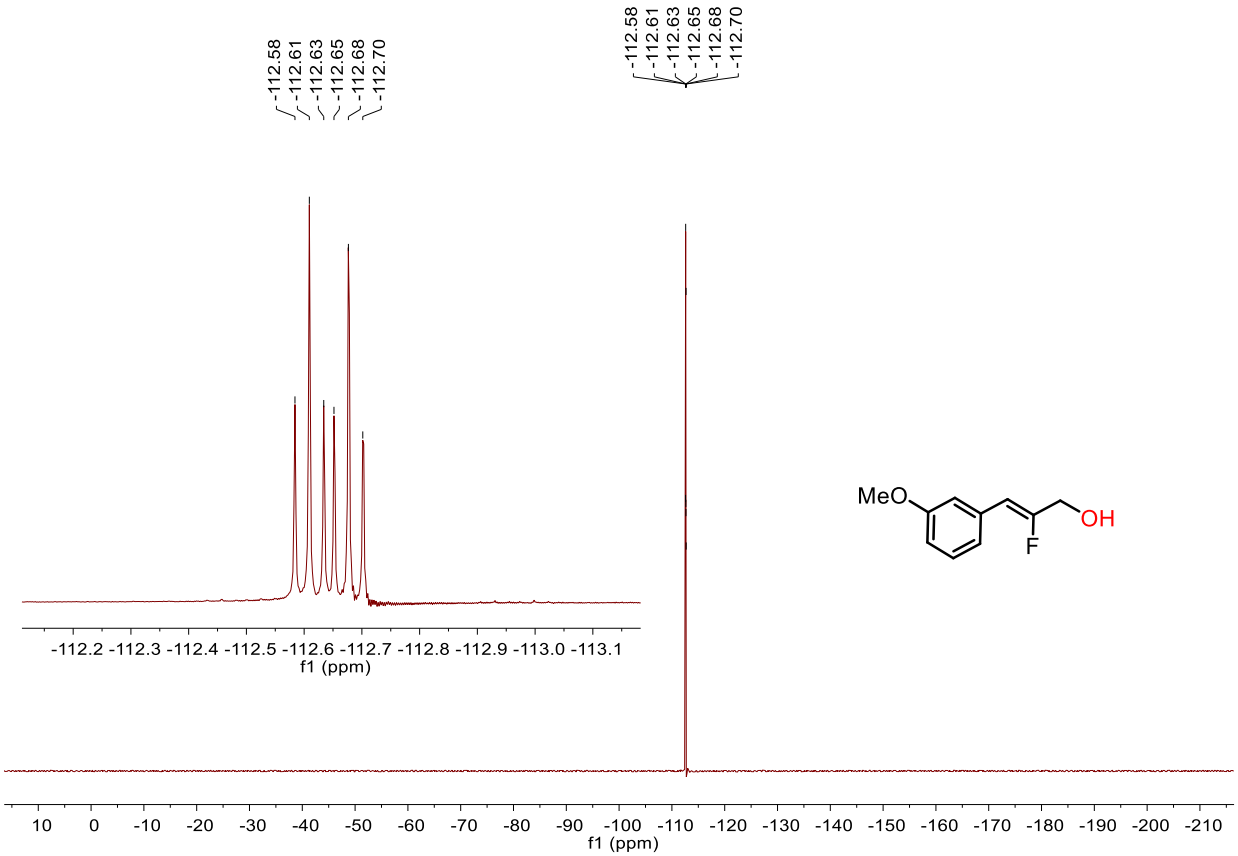
^{13}C NMR (product **2k**)



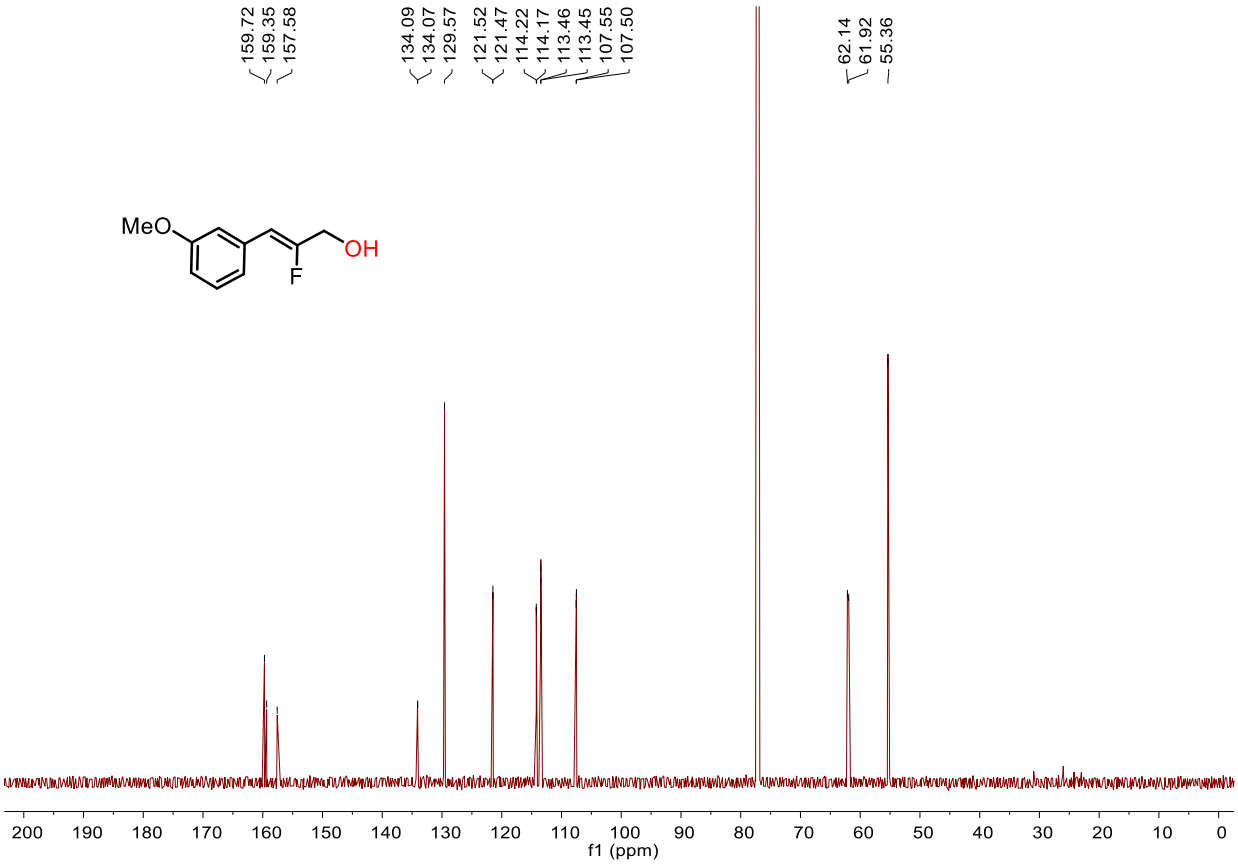
^{1}H NMR (product **2l**)



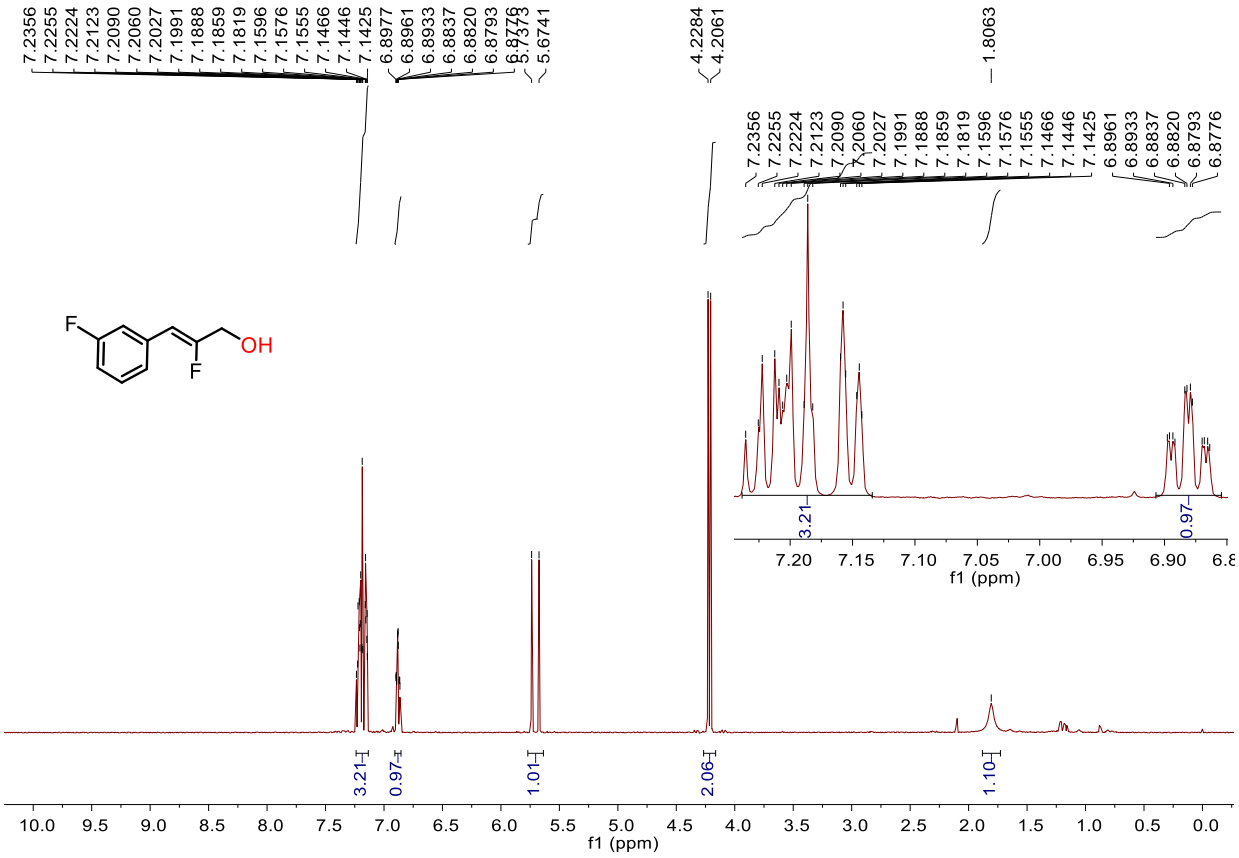
^{19}F NMR (product **2l**)



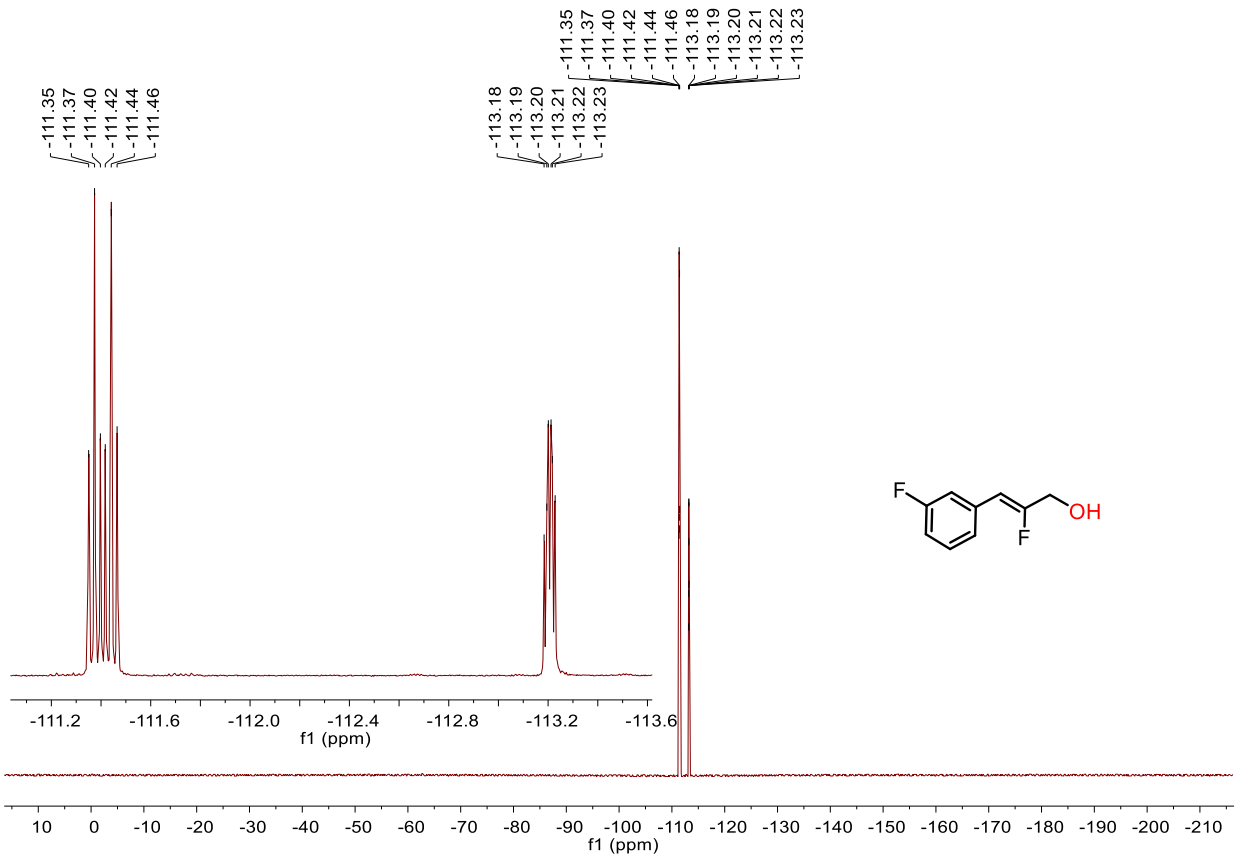
^{13}C NMR (product **2l**)



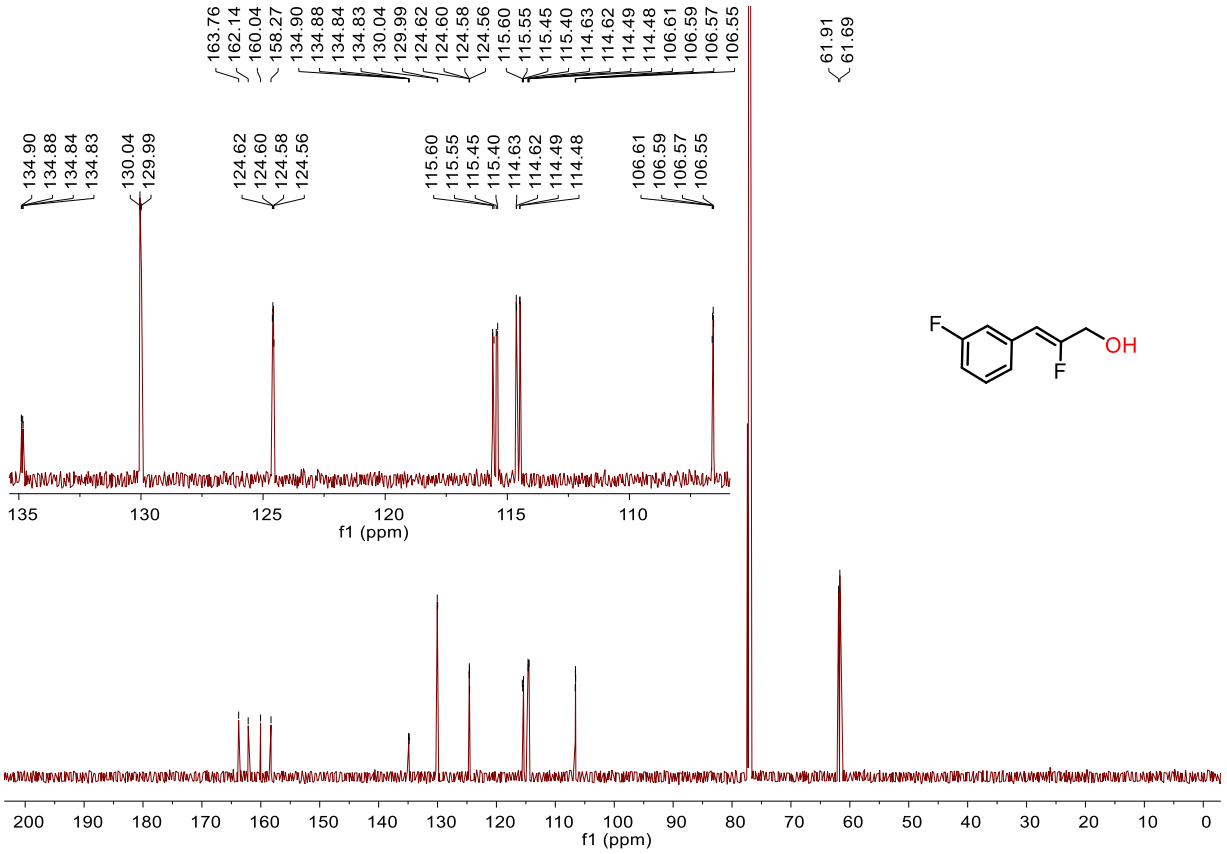
^{1}H NMR (product **2m**)



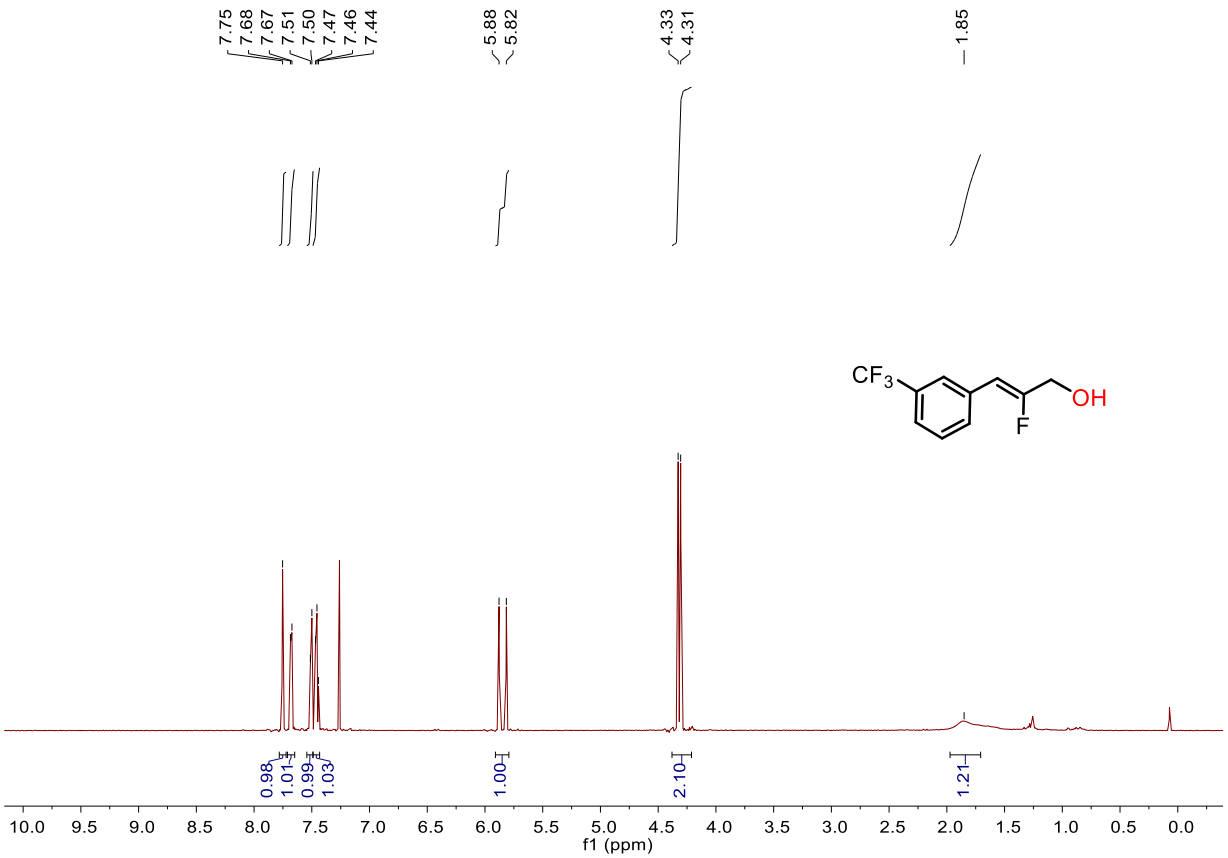
^{19}F NMR (product **2m**)



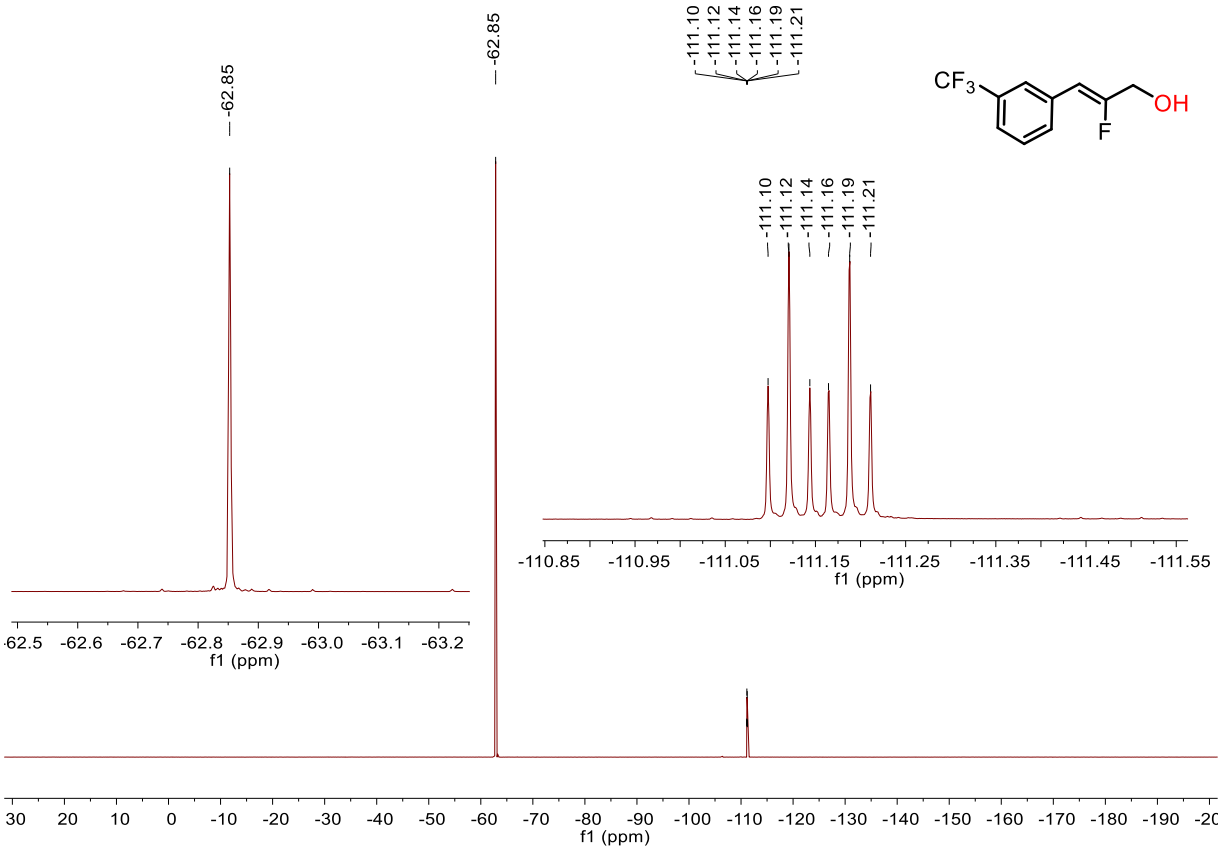
^{13}C NMR (product **2m**)



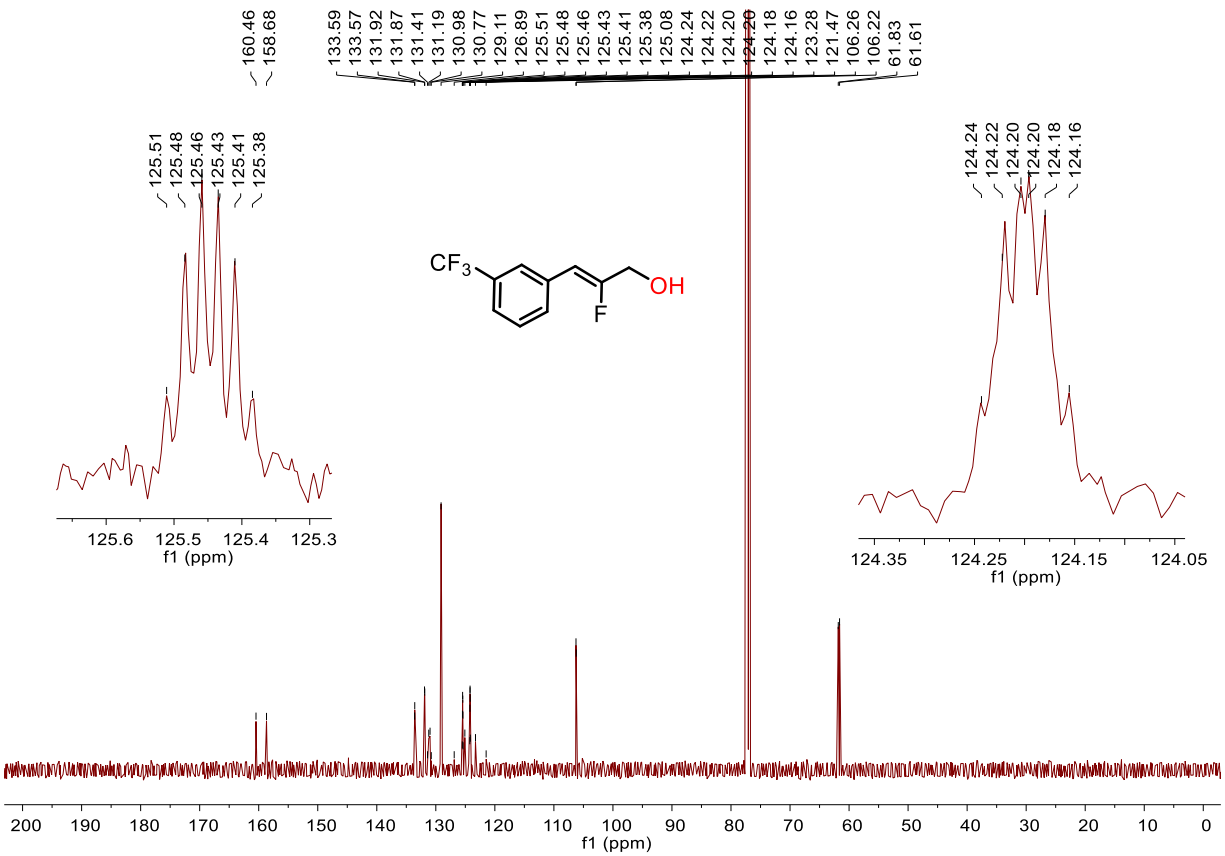
^{1}H NMR (product **2n**)



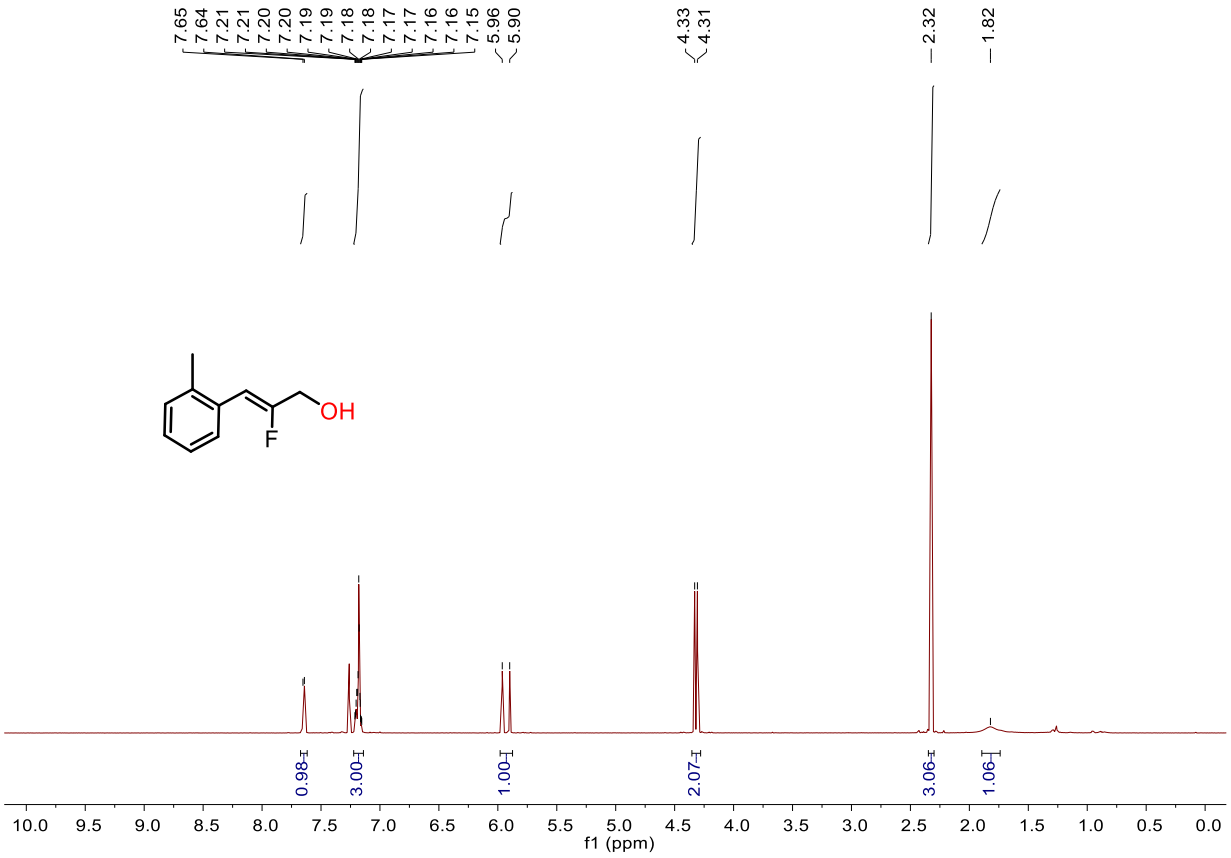
^{19}F NMR (product **2n**)



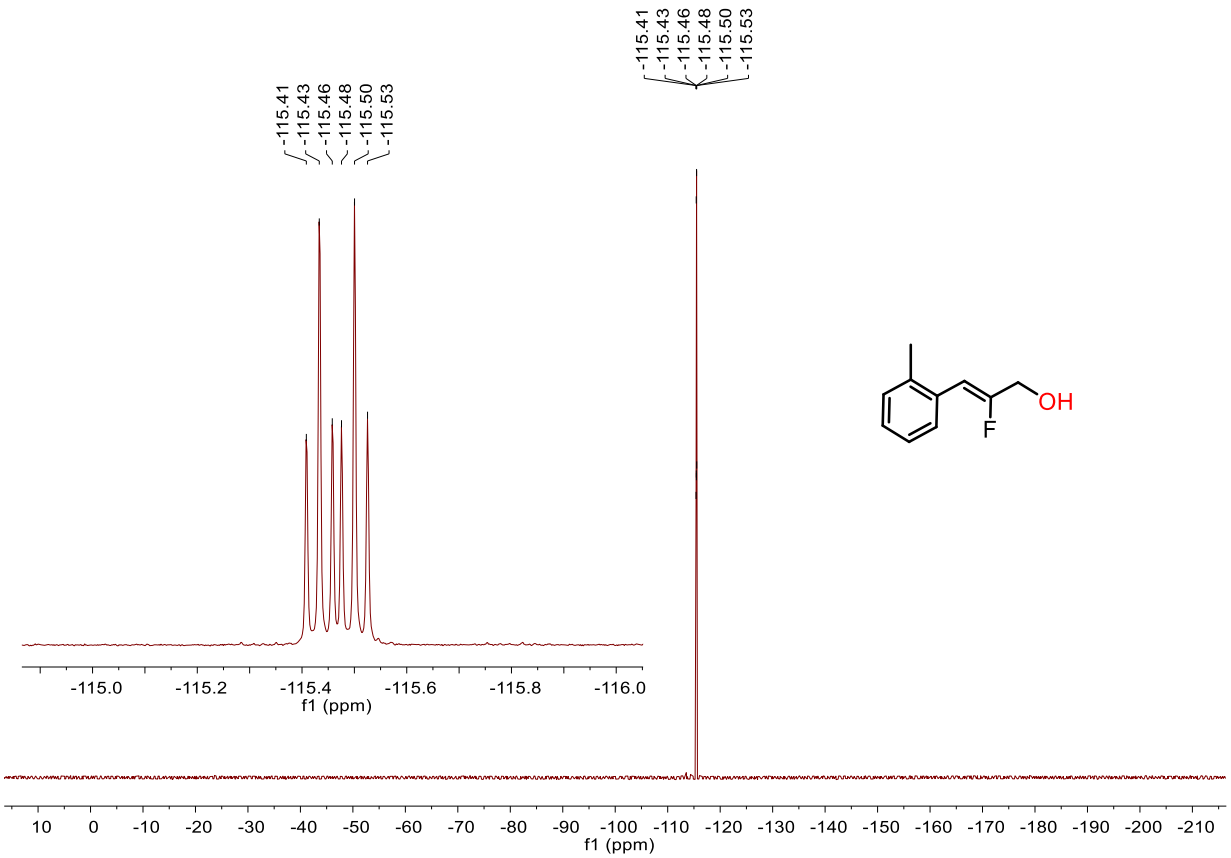
^{13}C NMR (product **2n**)



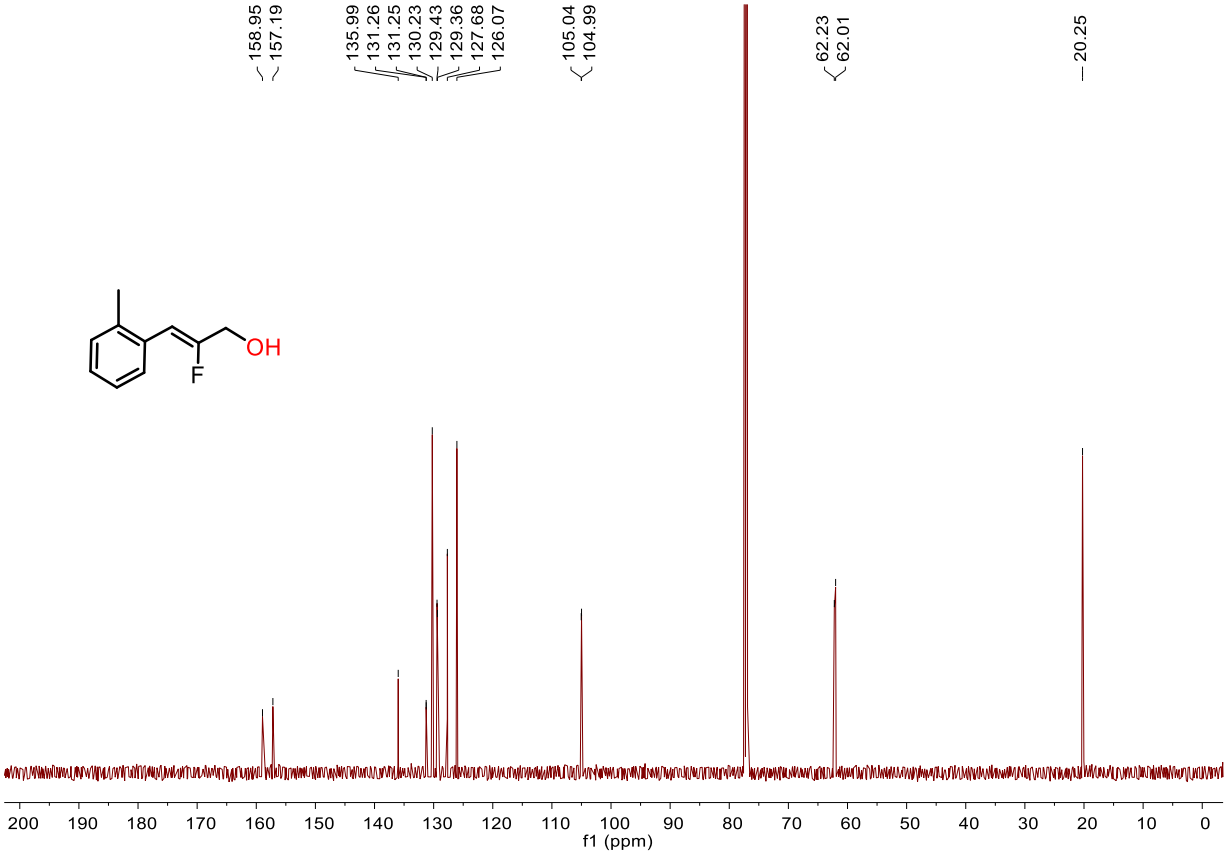
^{1}H NMR (product **2o**)



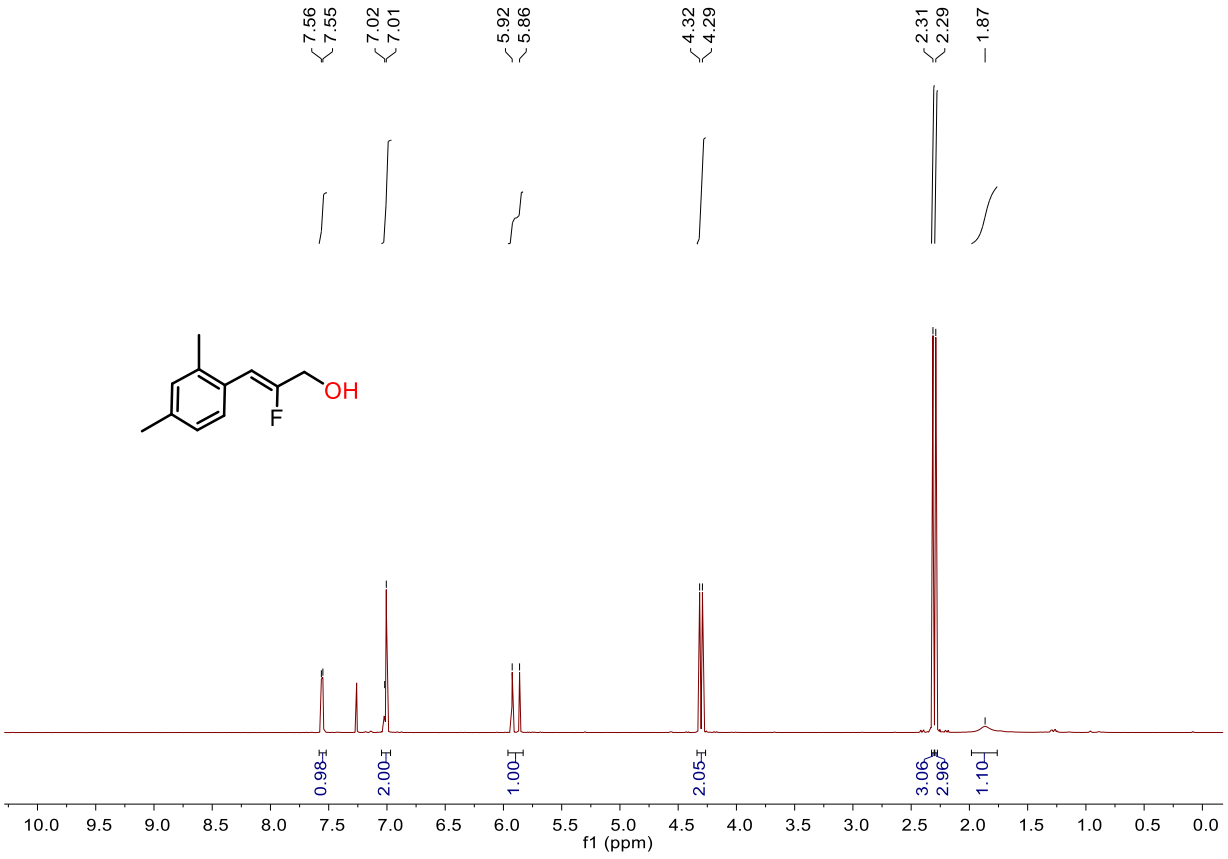
^{19}F NMR (product **2o**)



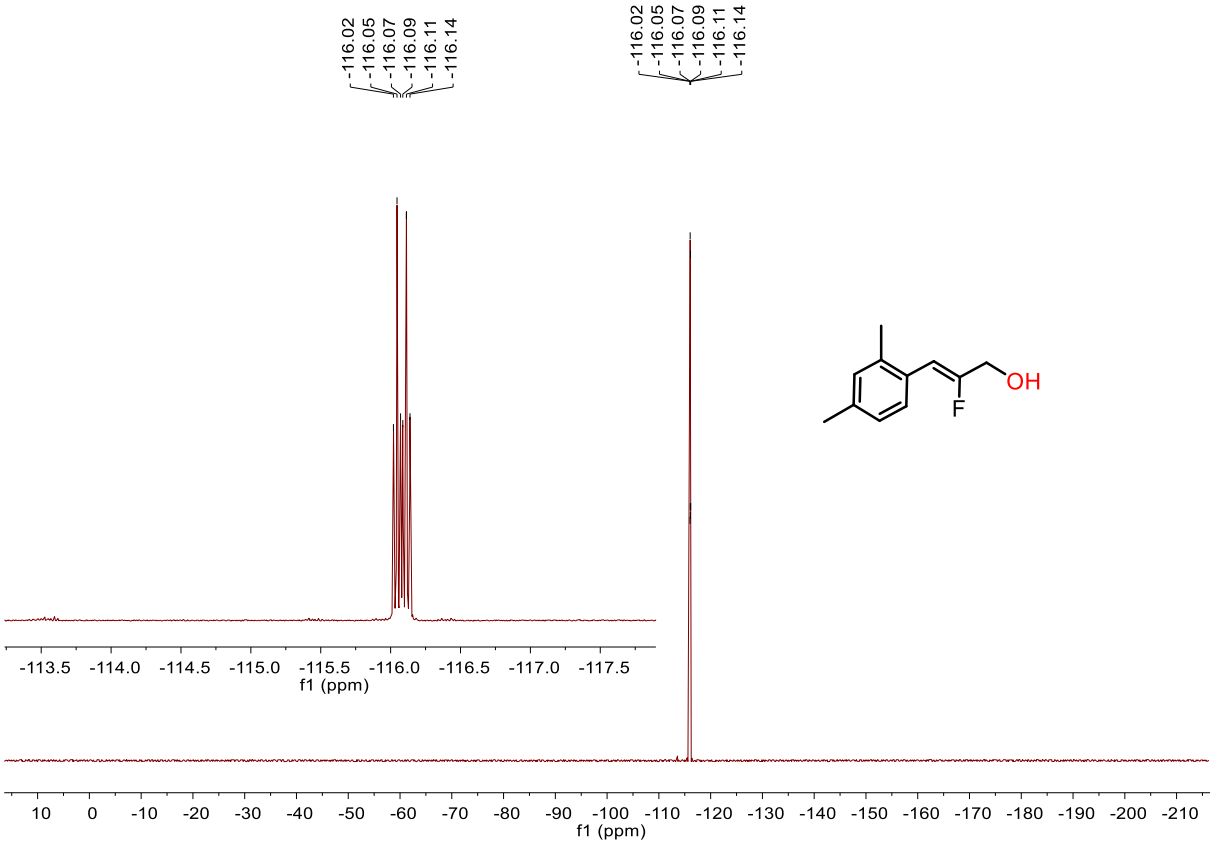
^{13}C NMR (product **2o**)



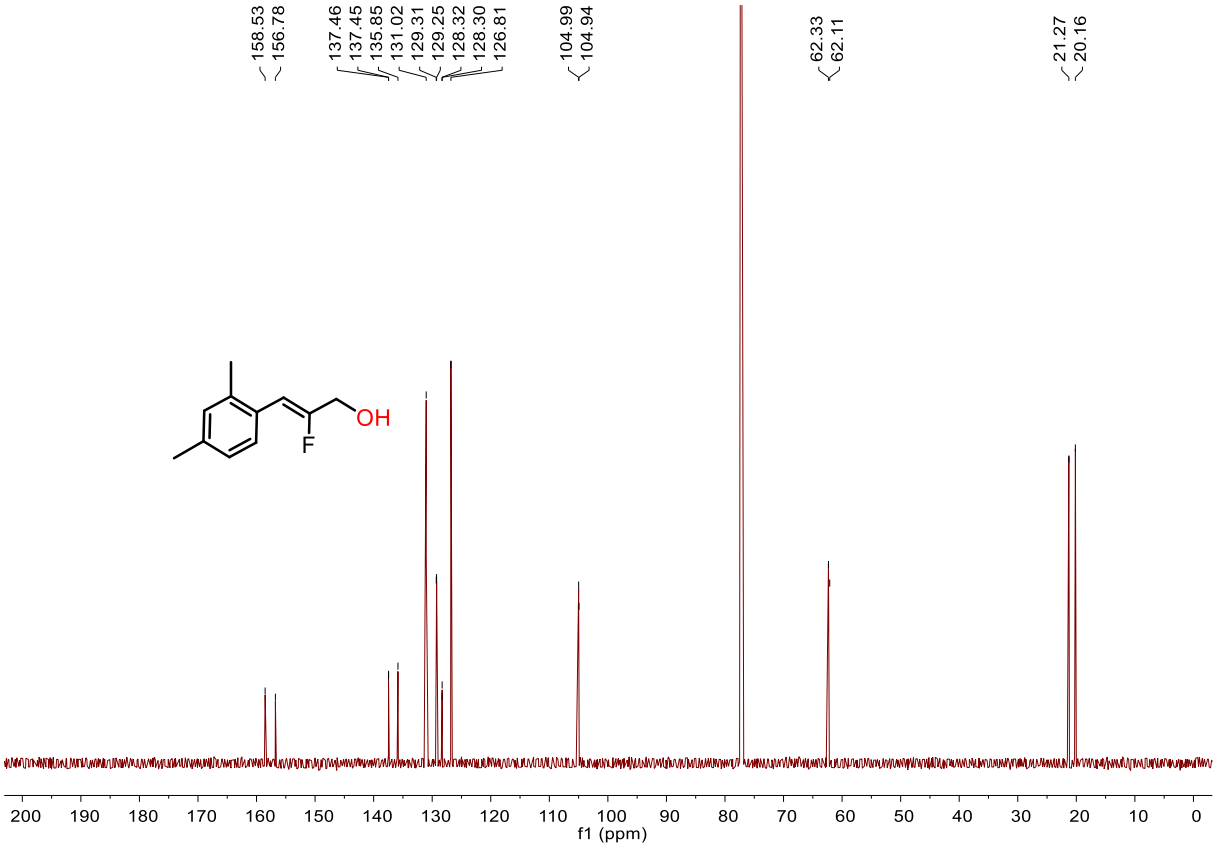
^{1}H NMR (product **2p**)



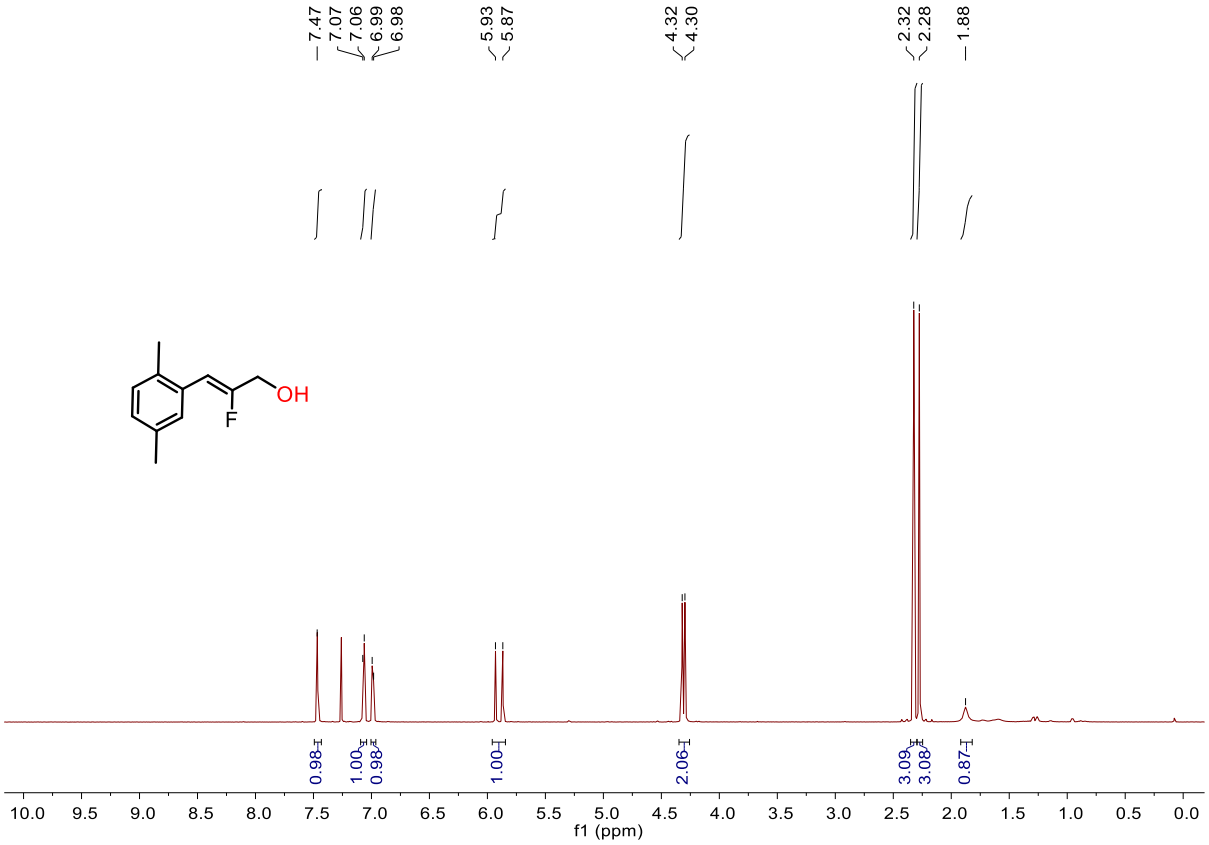
^{19}F NMR (product **2p**)



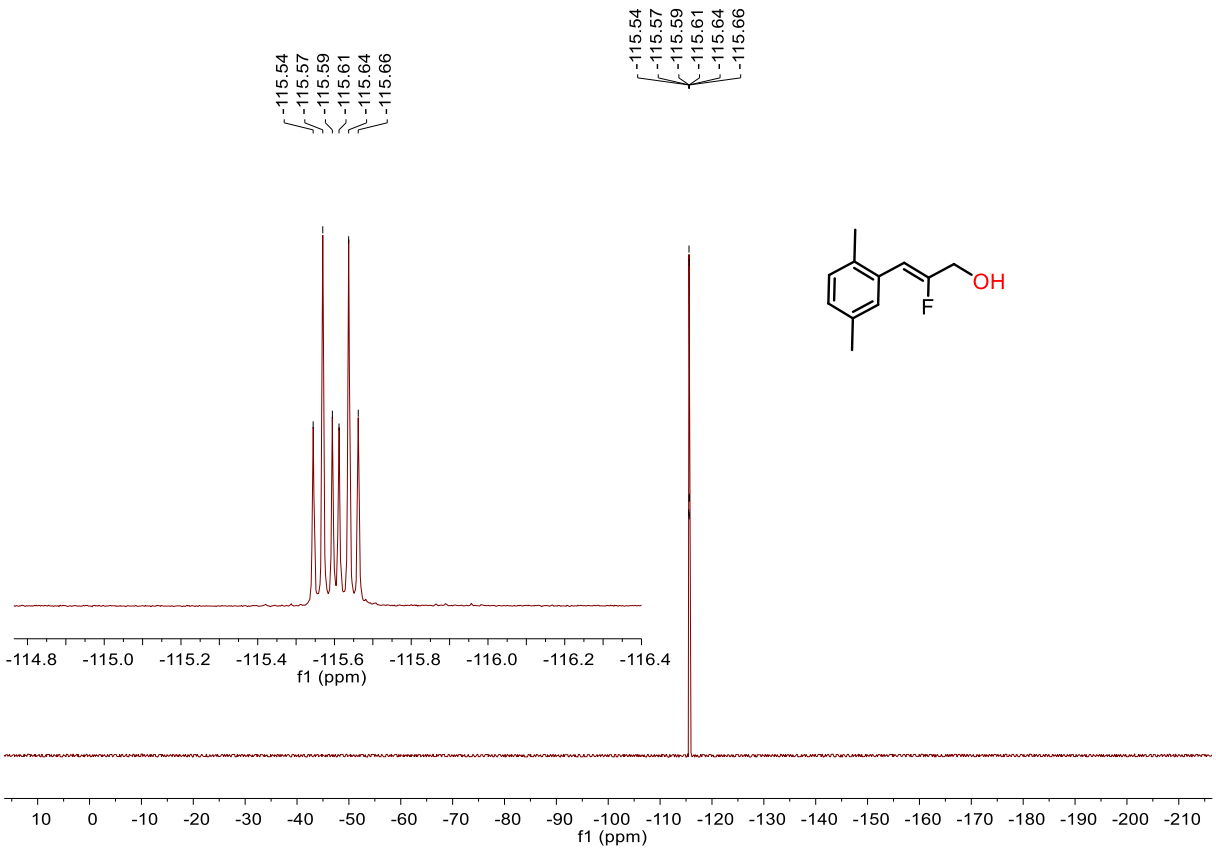
^{13}C NMR (product **2p**)



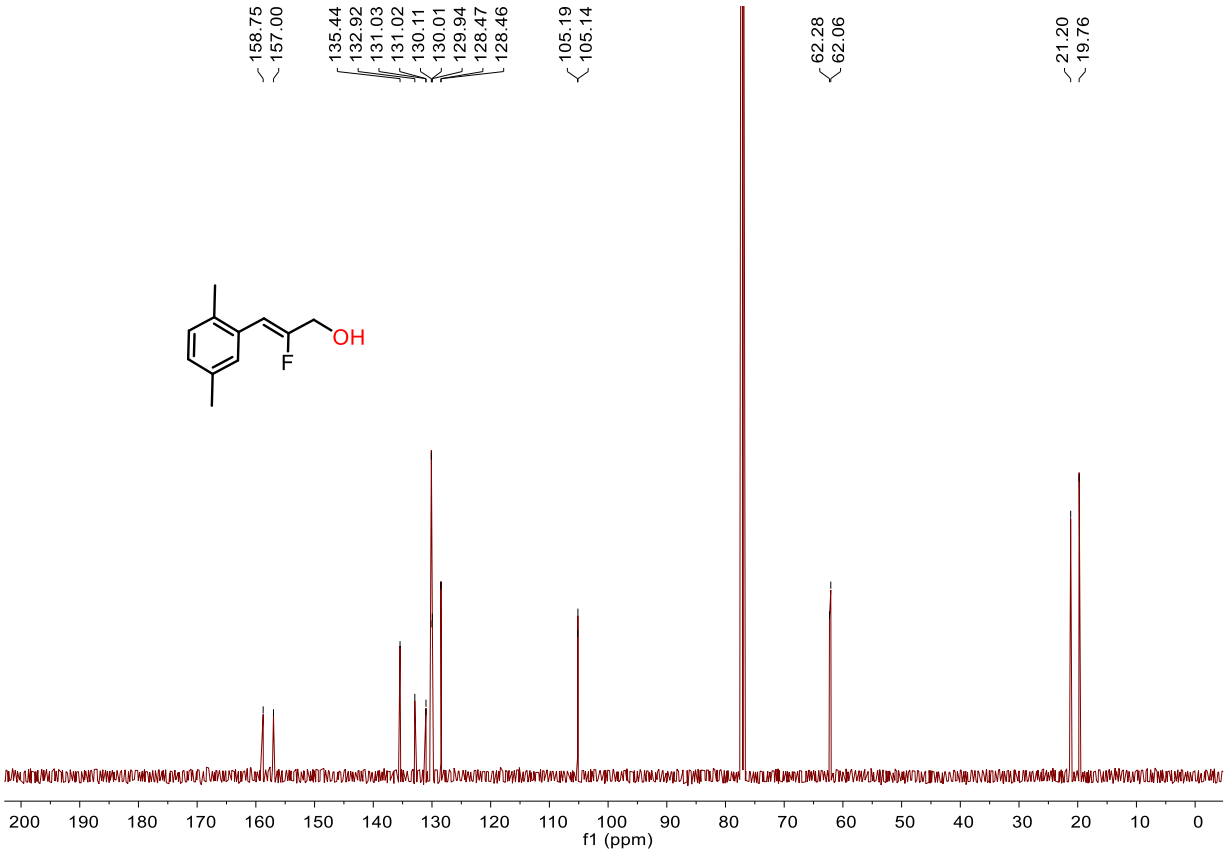
^{1}H NMR (product **2q**)



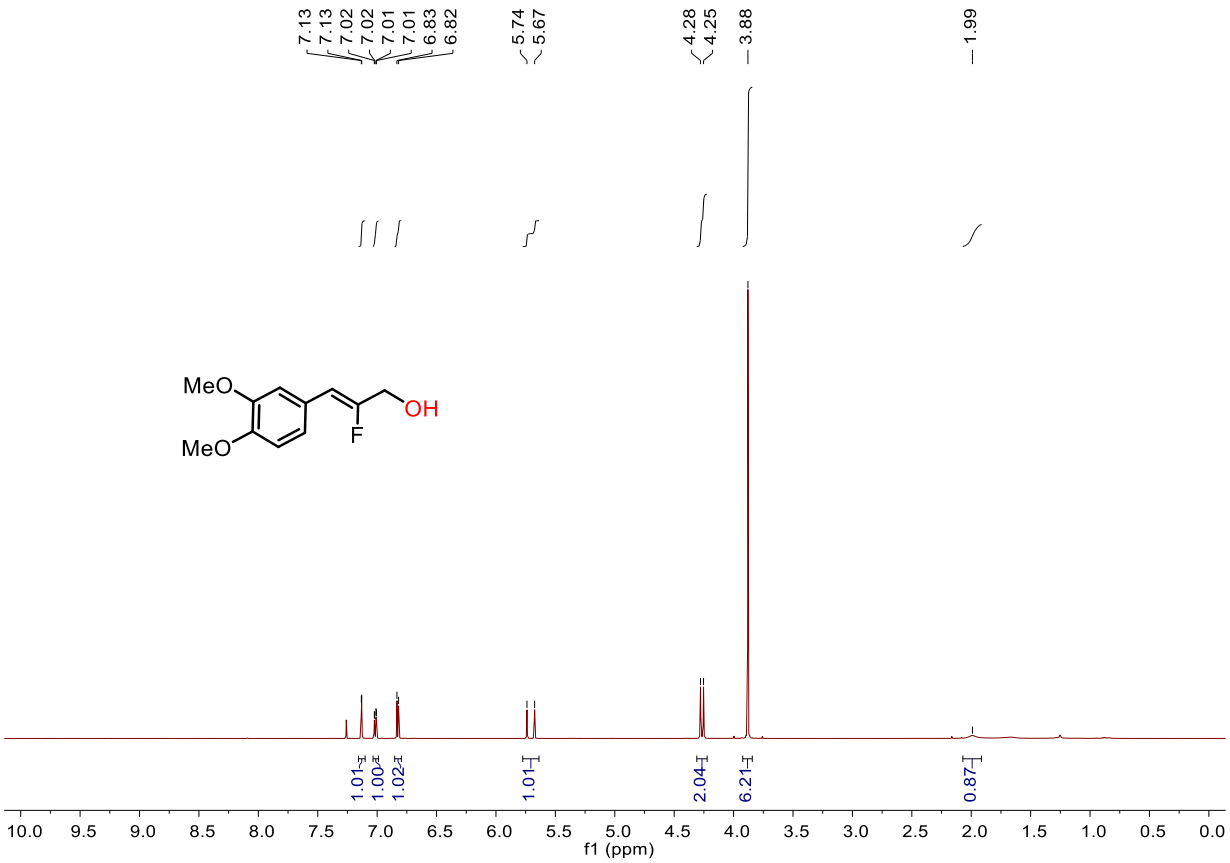
^{19}F NMR (product **2q**)



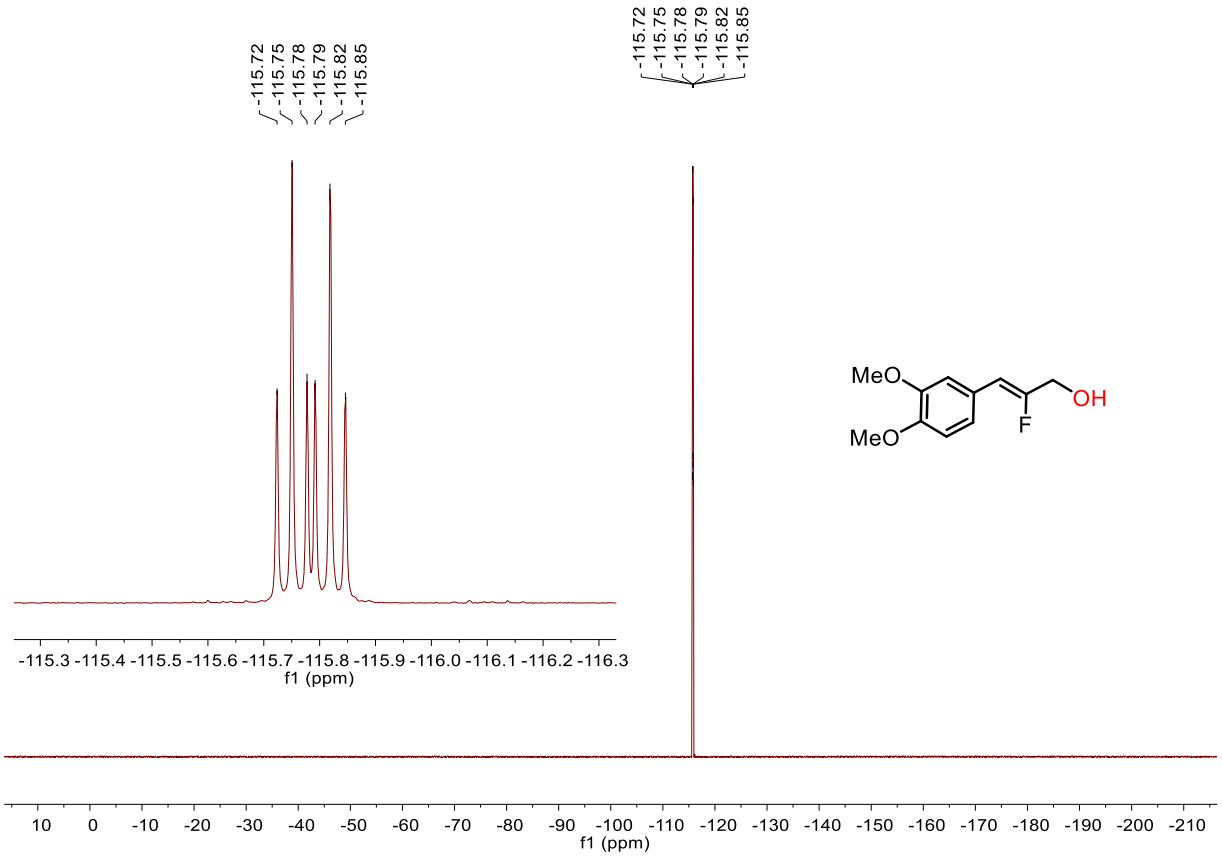
^{13}C NMR (product **2q**)



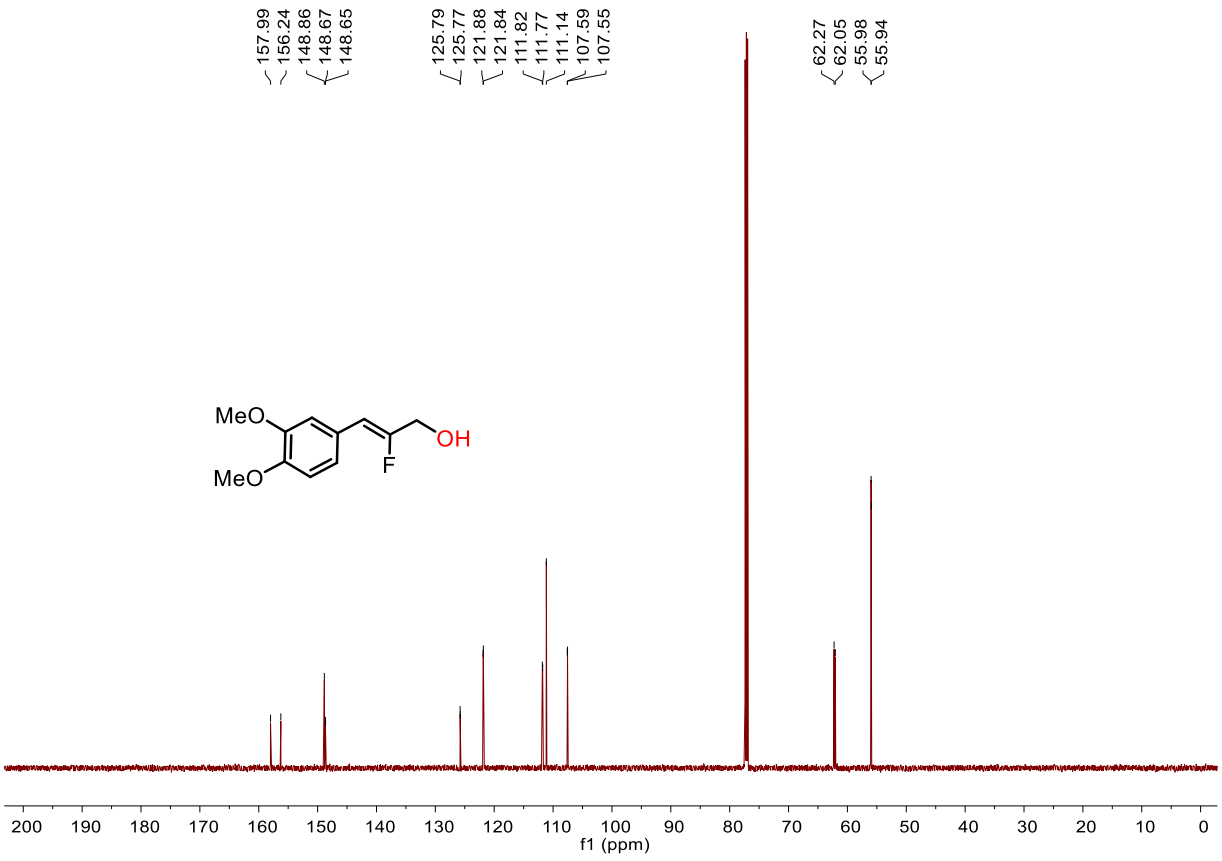
^{1}H NMR (product **2r**)



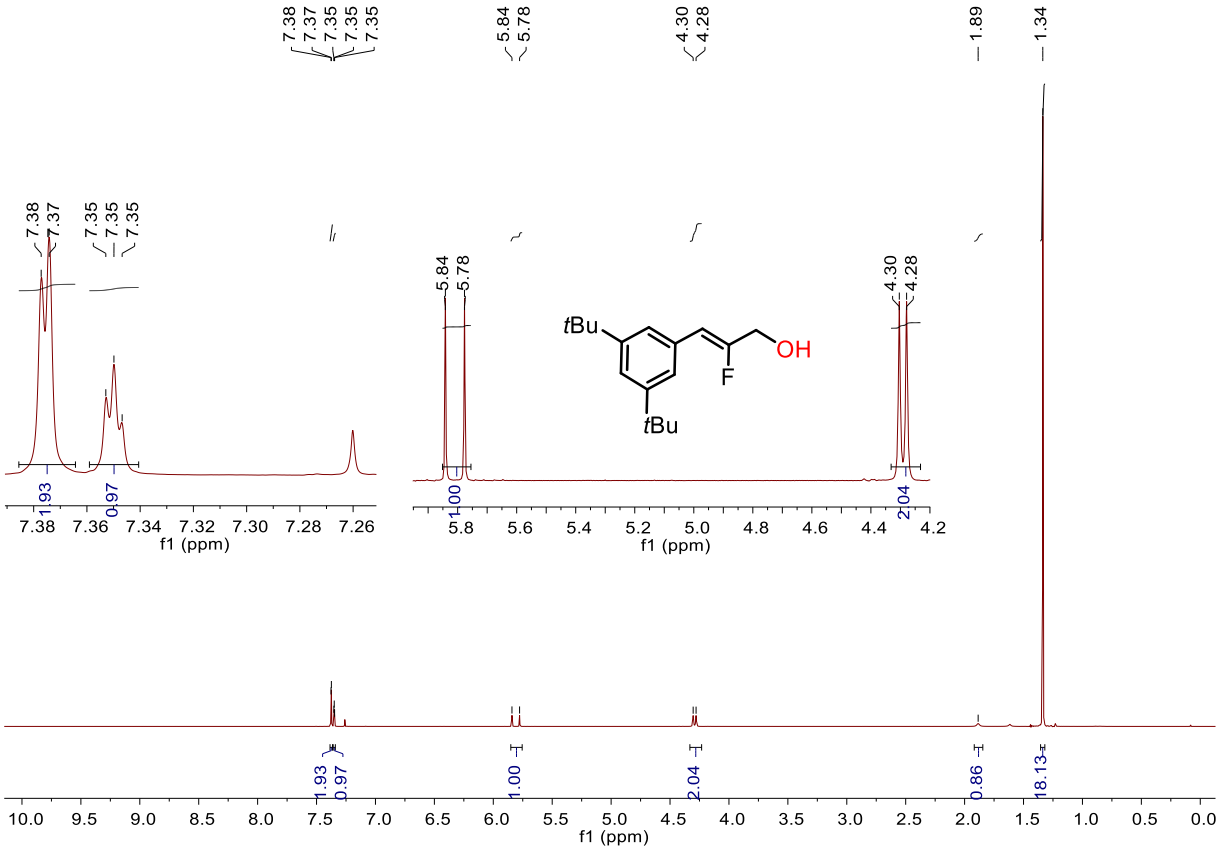
^{19}F NMR (product **2r**)



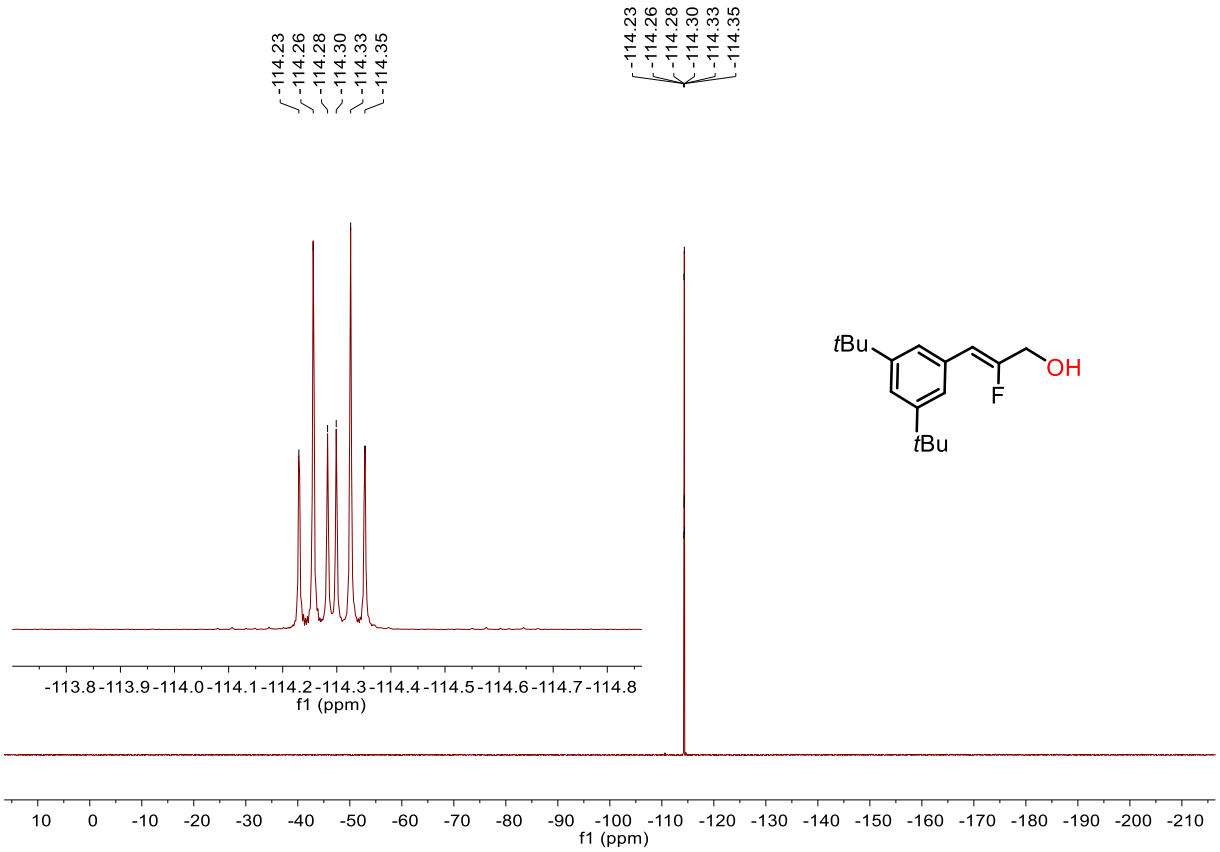
^{13}C NMR (**2r**)



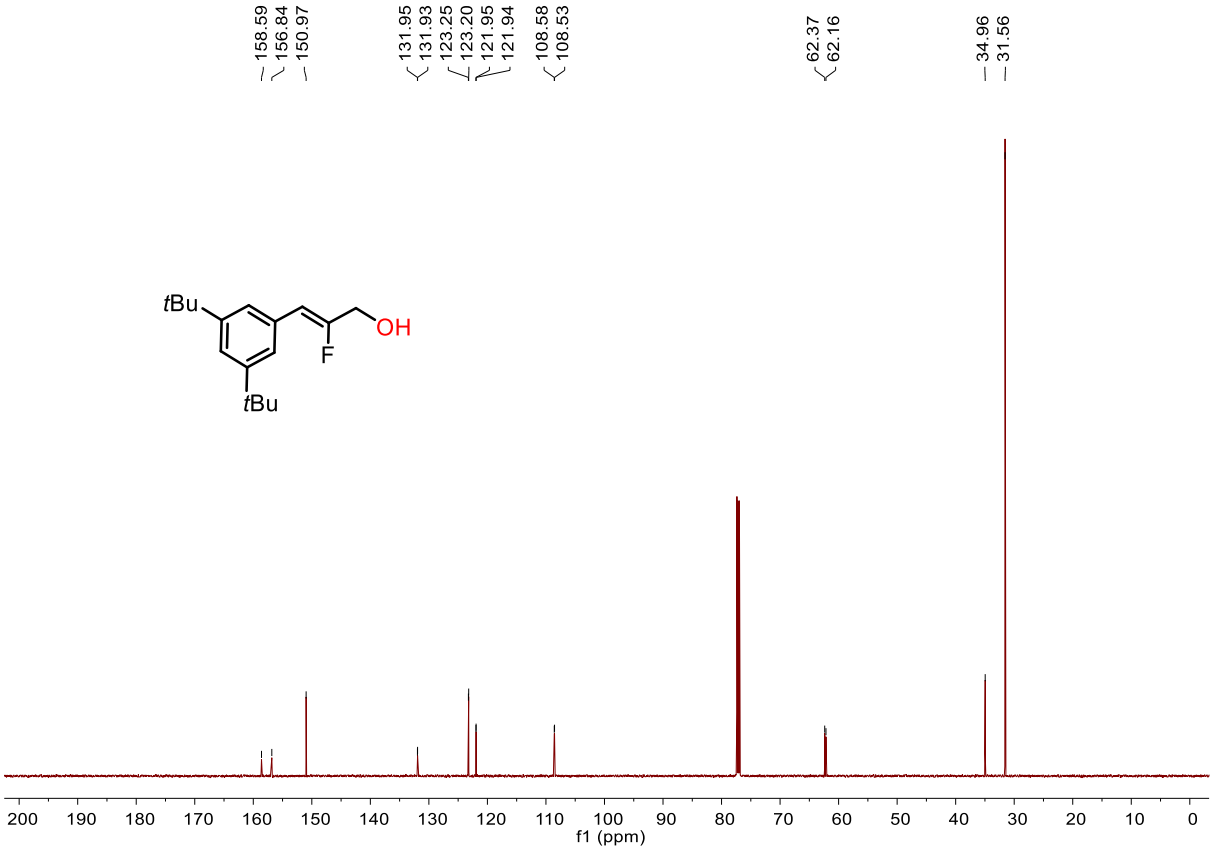
^{1}H NMR (product **2s**)



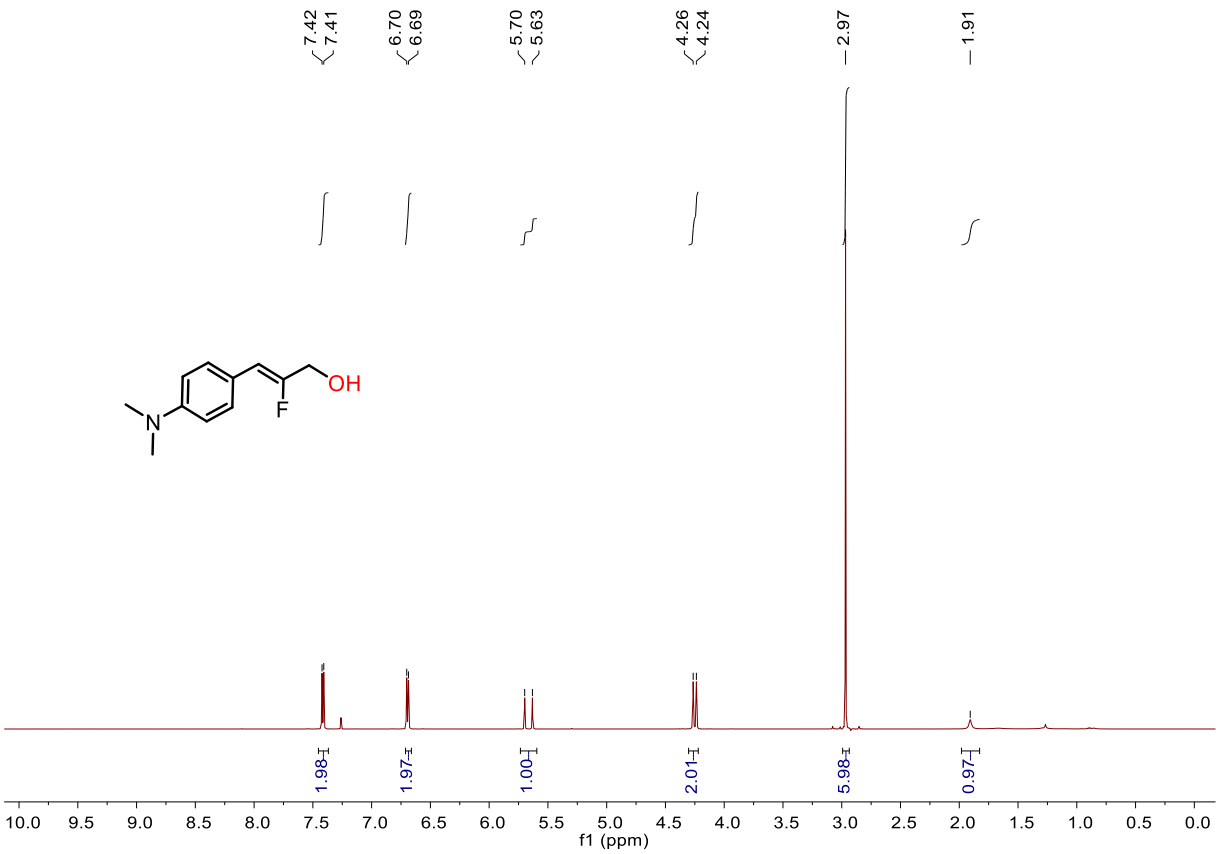
^{19}F NMR (product **2s**)



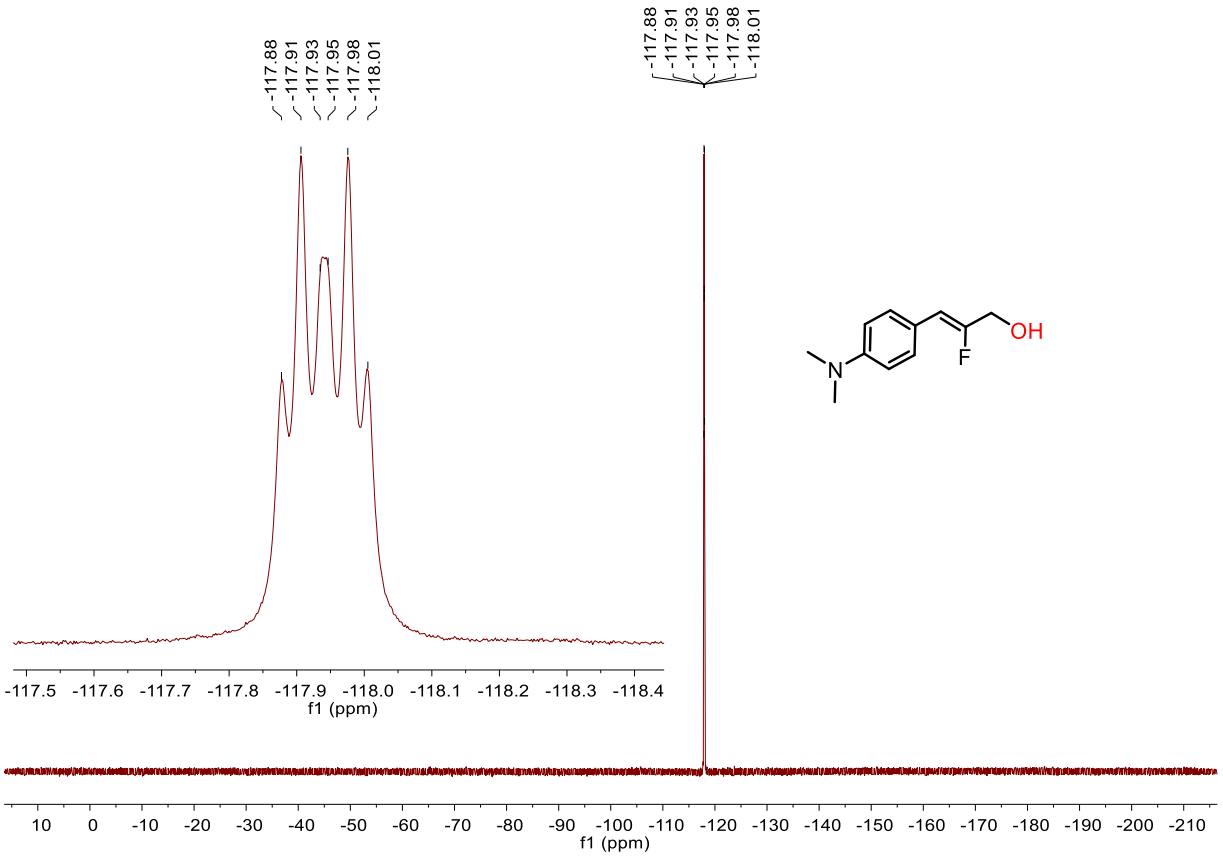
^{13}C NMR (product **2s**)



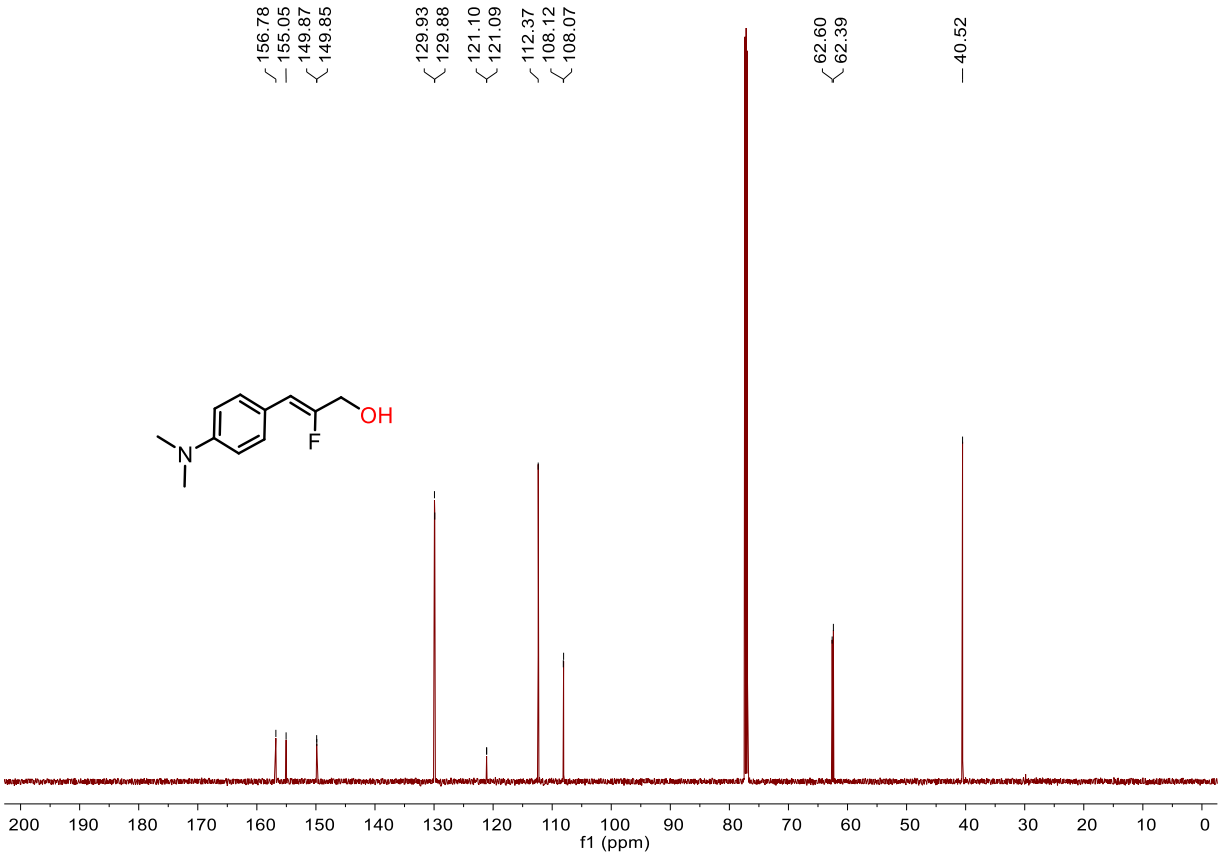
^{1}H NMR (product **2t**)



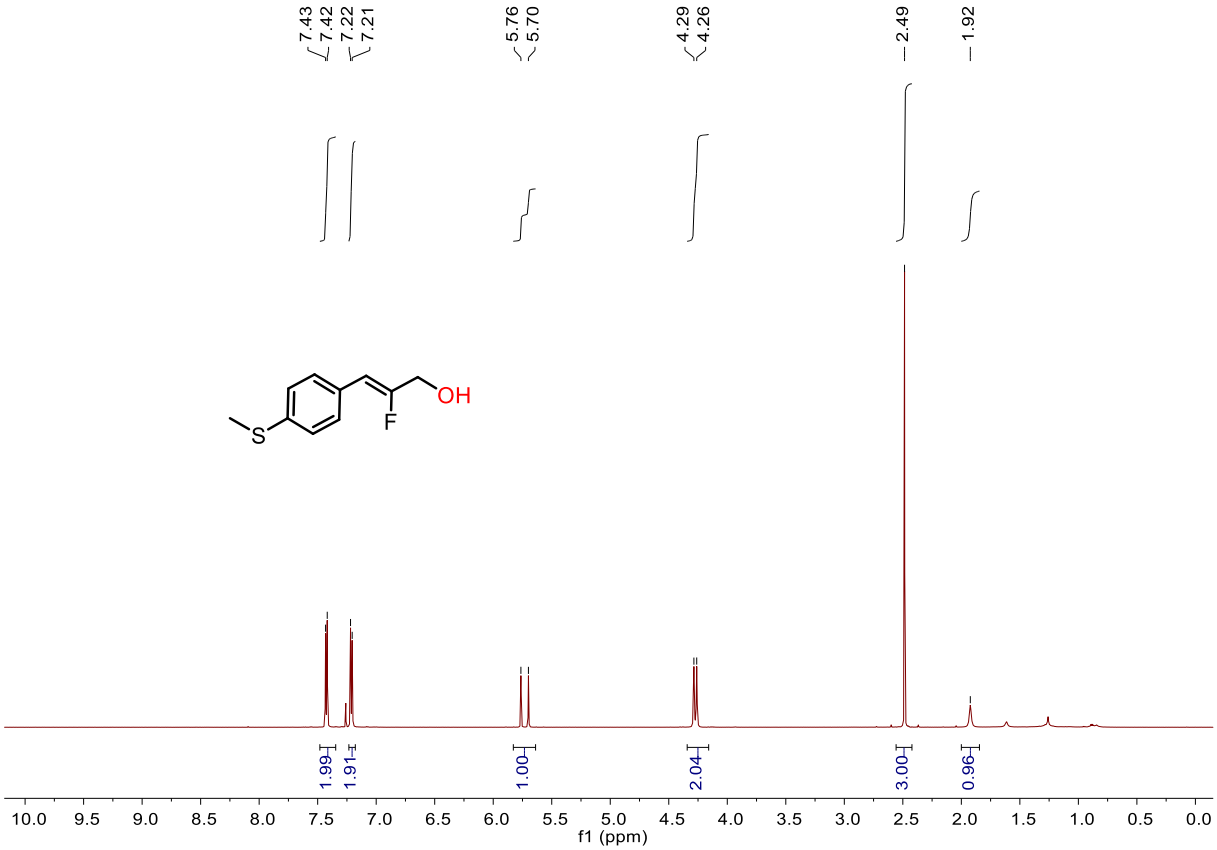
^{19}F NMR (product **2t**)



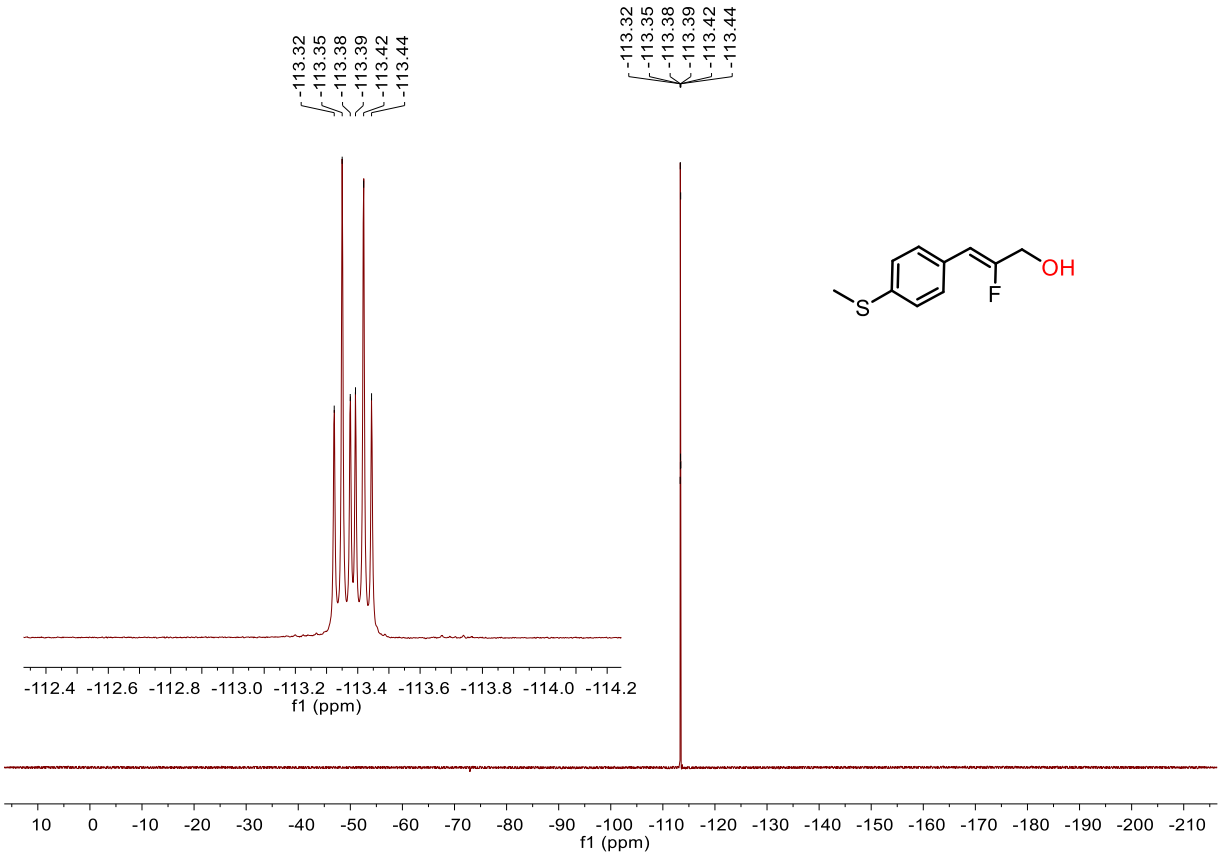
^{13}C NMR (**2t**)



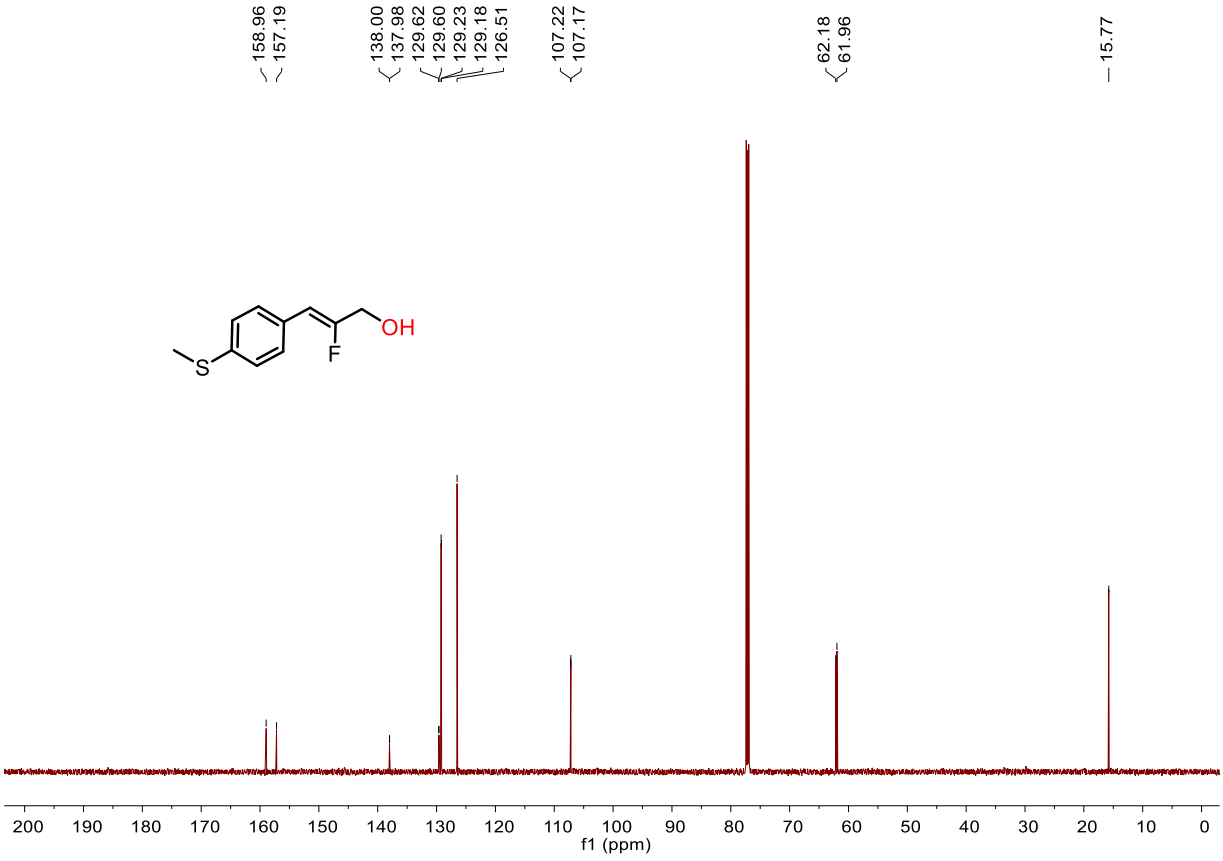
^{1}H NMR (product **2u**)



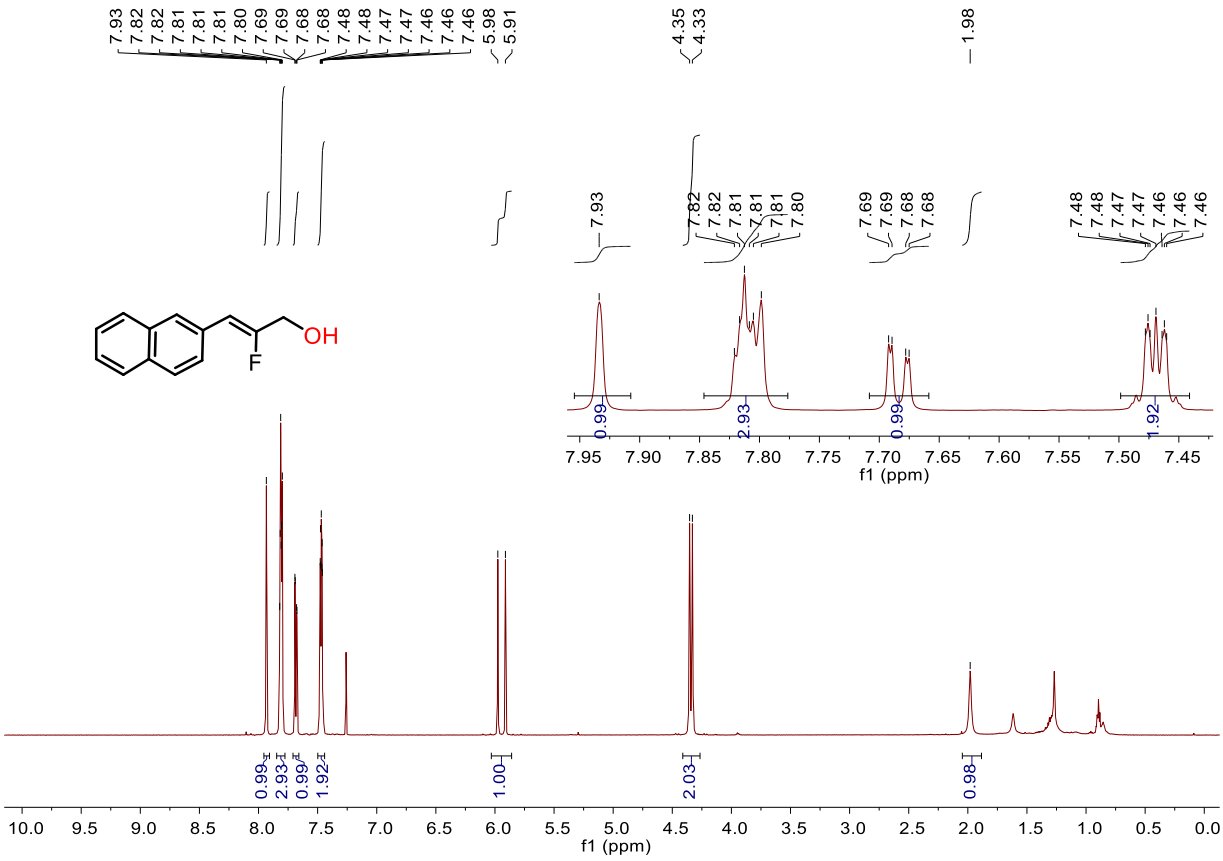
^{19}F NMR (product **2u**)



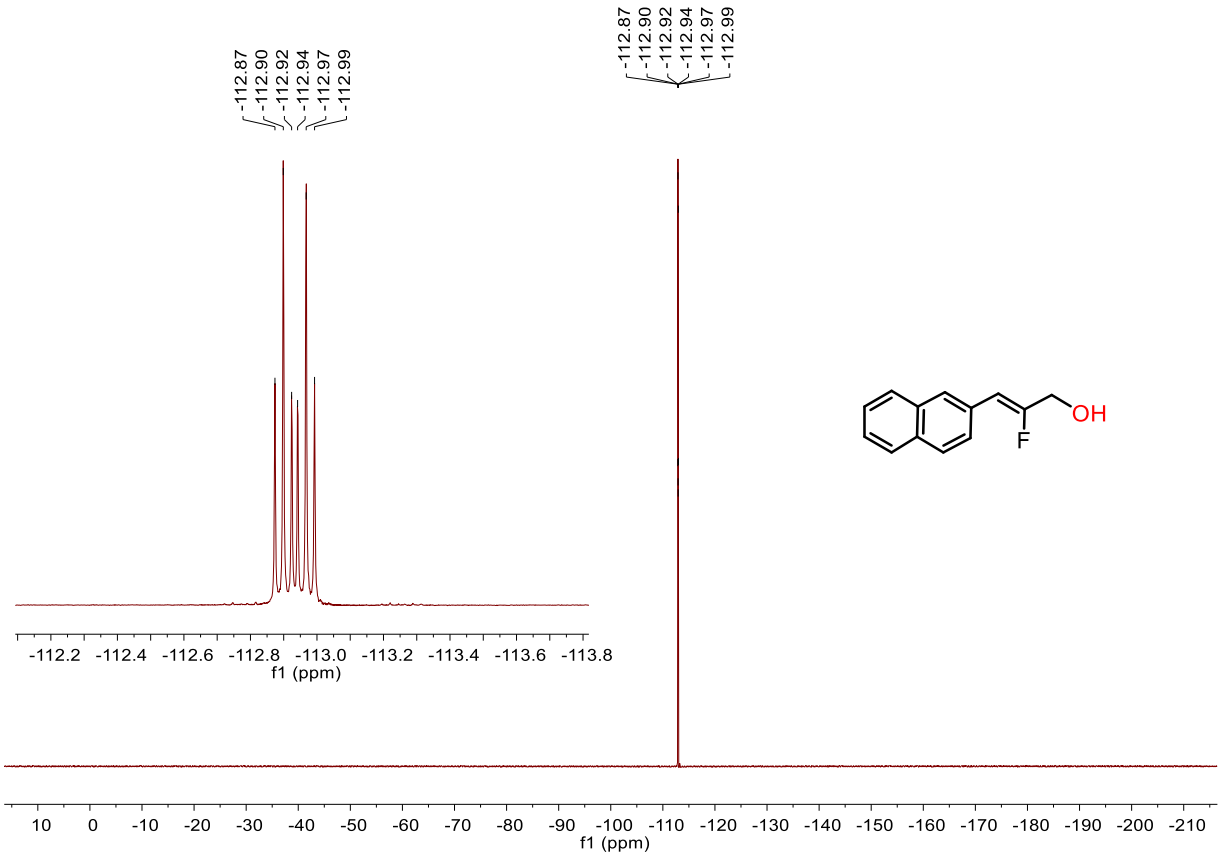
^{13}C NMR (product **2u**)



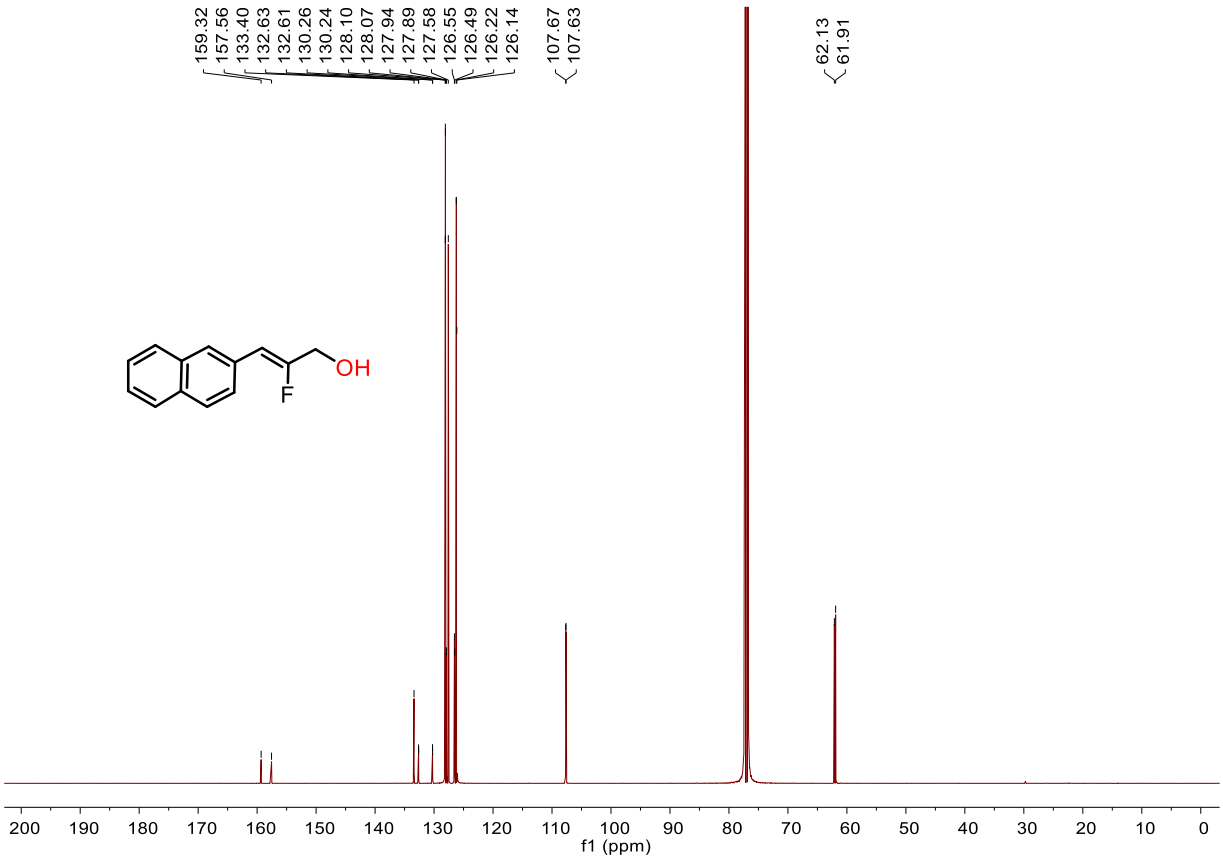
^{1}H NMR (product **2v**)



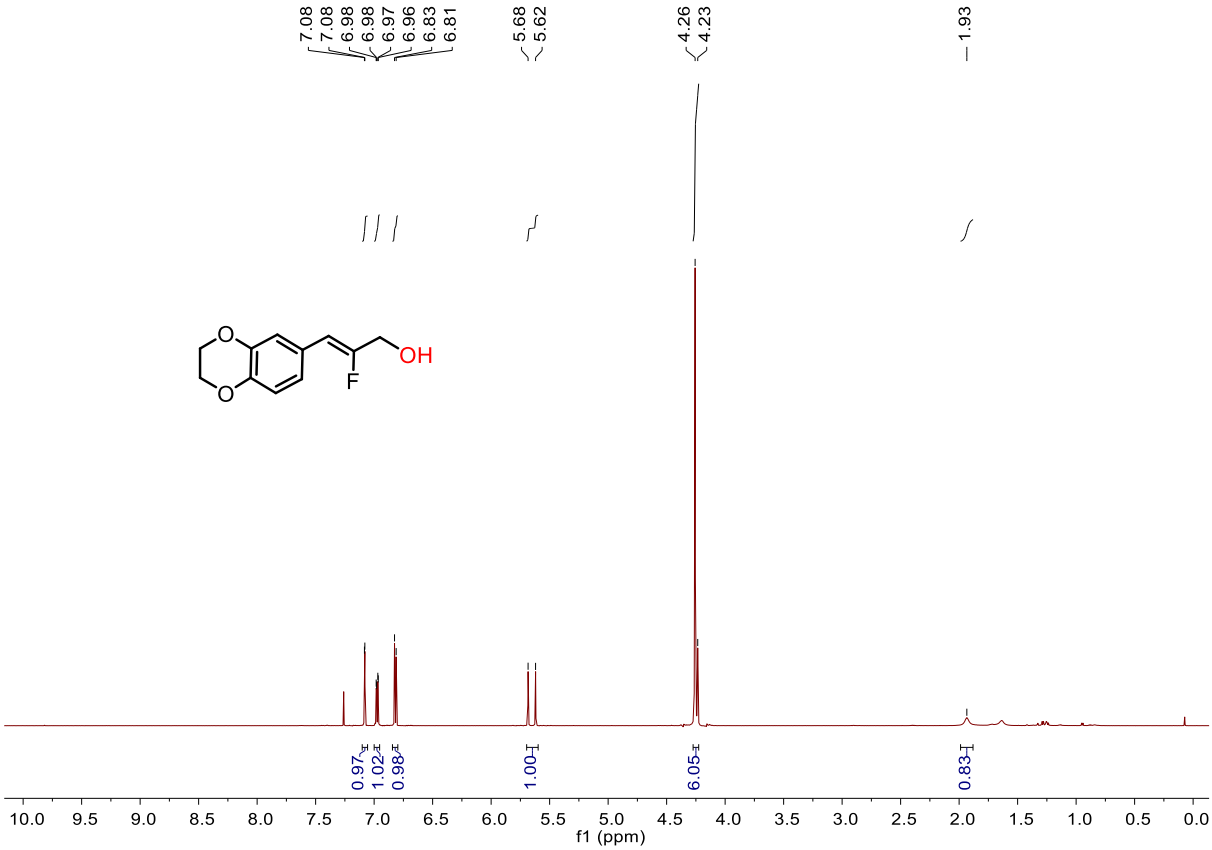
^{19}F NMR (product **2v**)



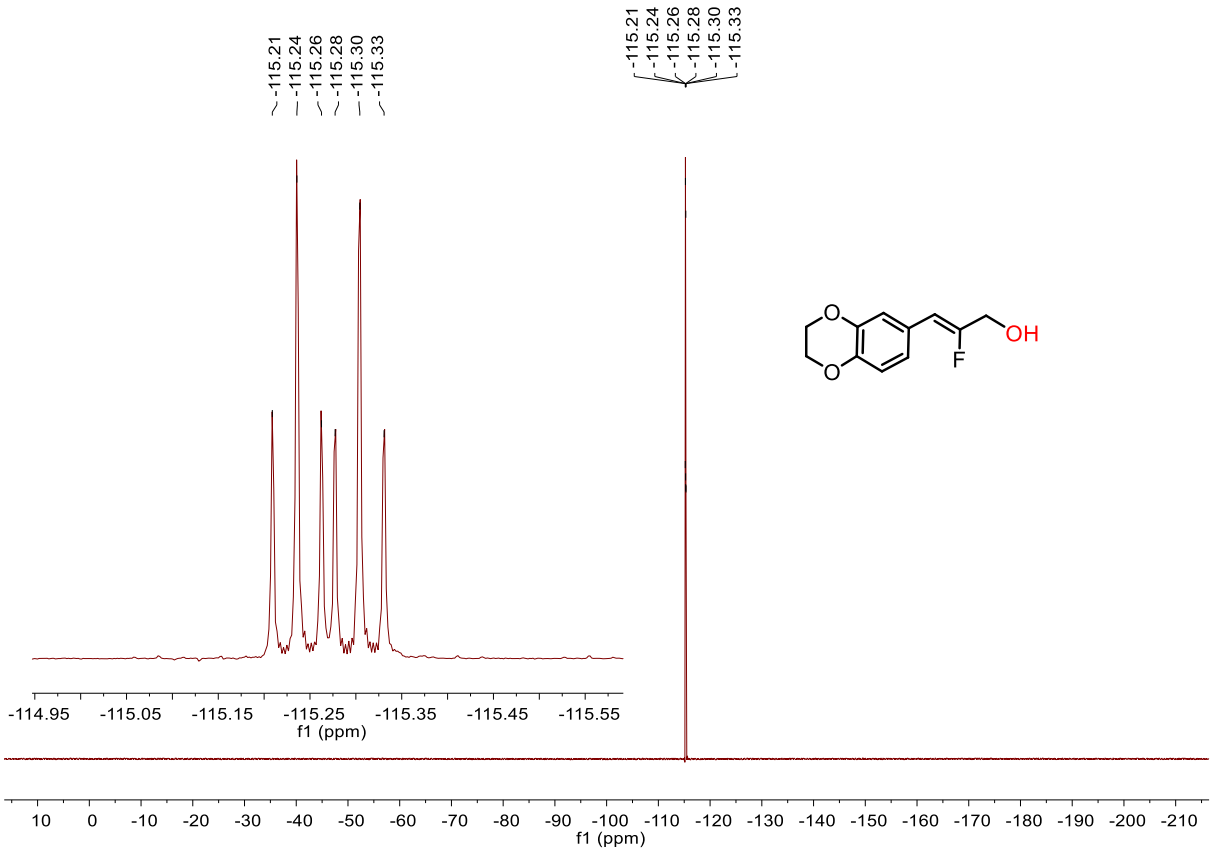
^{13}C NMR (product **2v**)



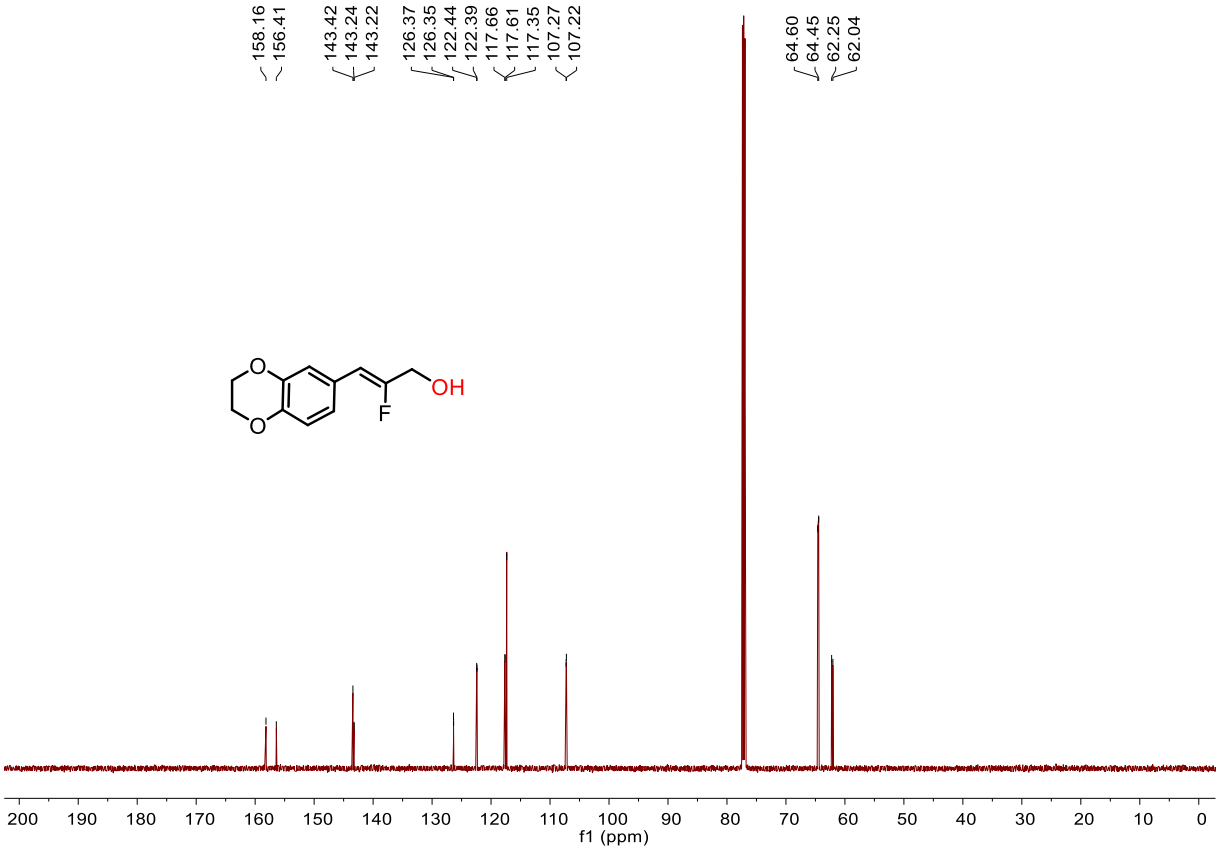
^{1}H NMR (product **2w**)



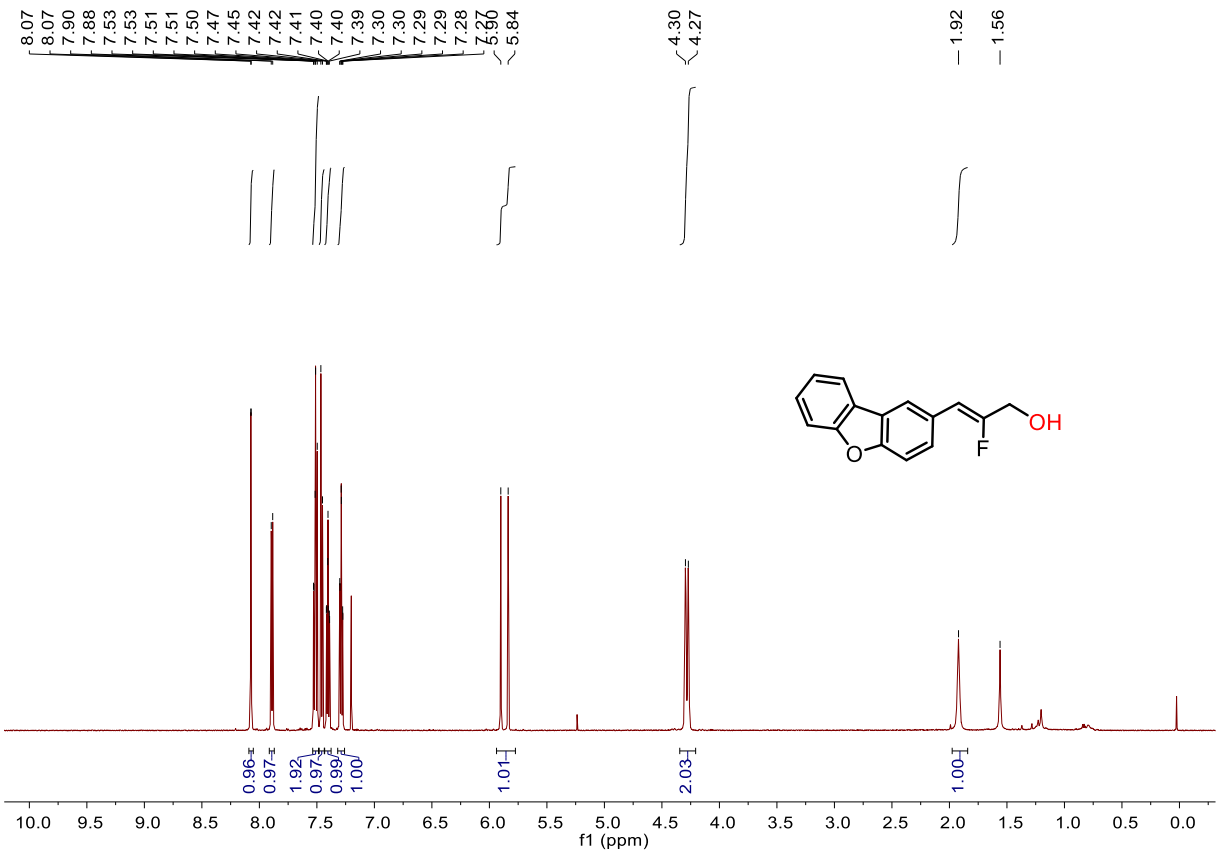
^{19}F NMR (product **2w**)



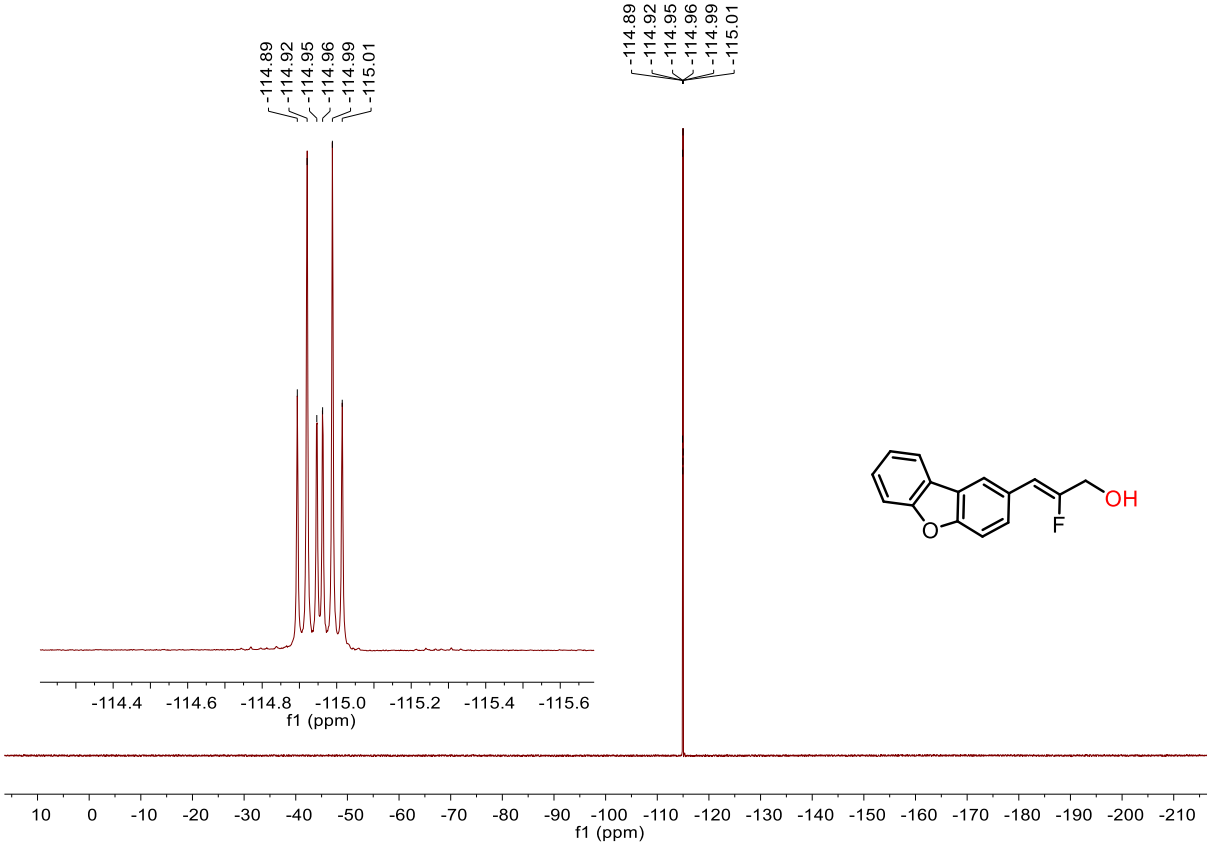
^{13}C NMR (product **2w**)



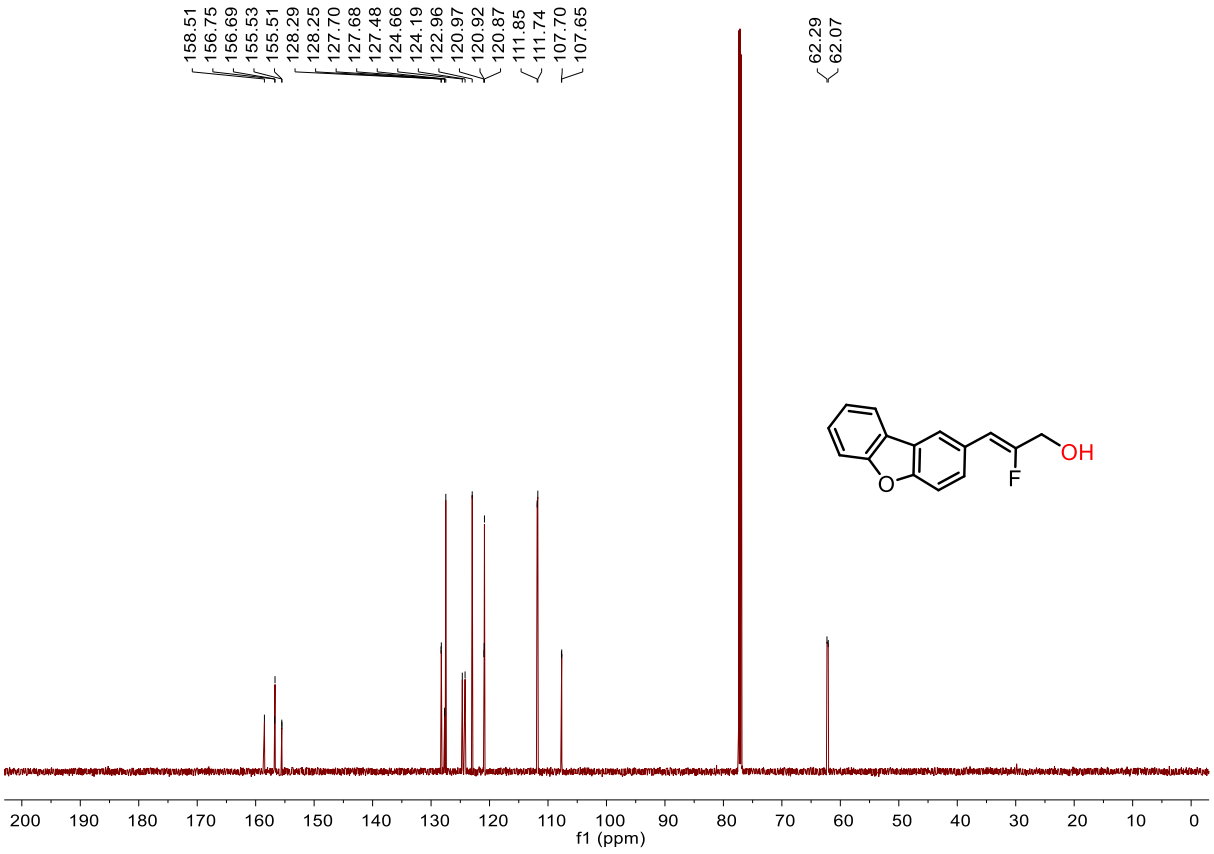
^{1}H NMR (product **2x**)



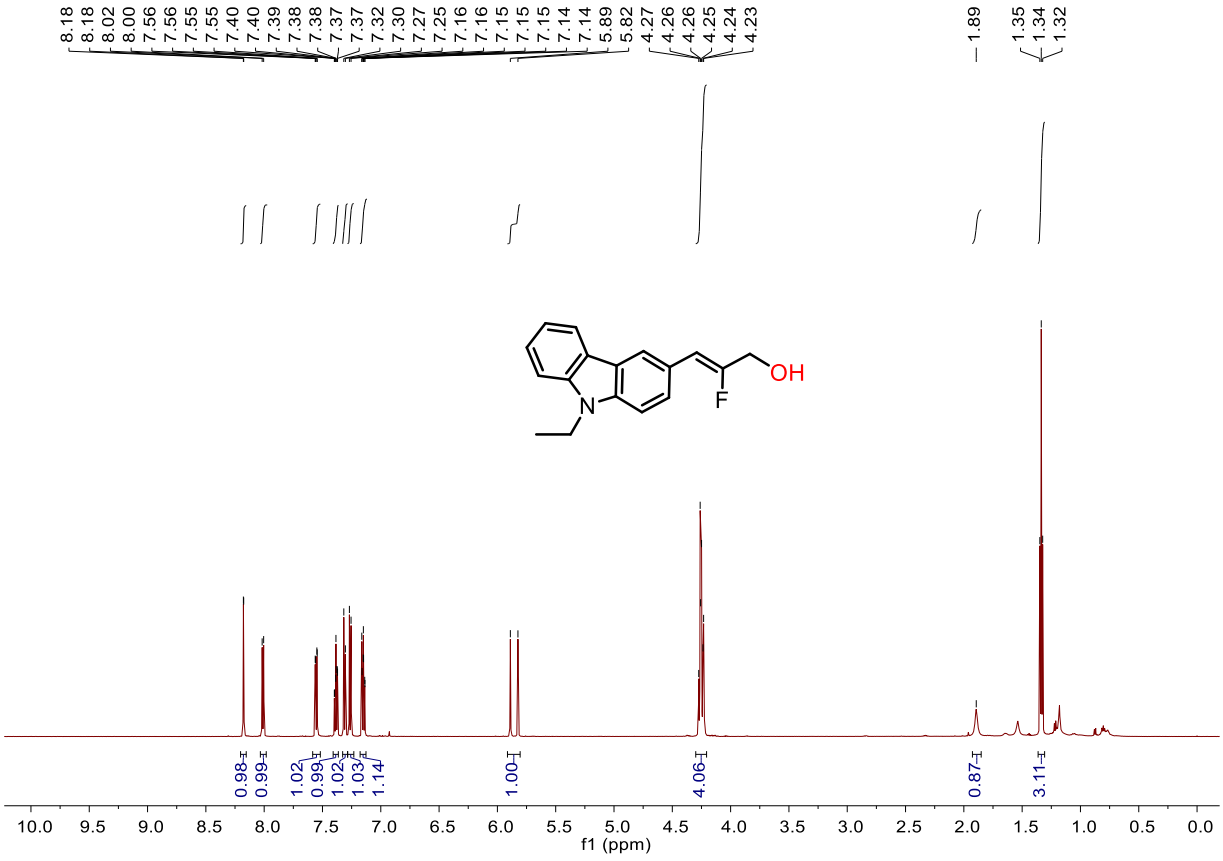
^{19}F NMR (product **2x**)



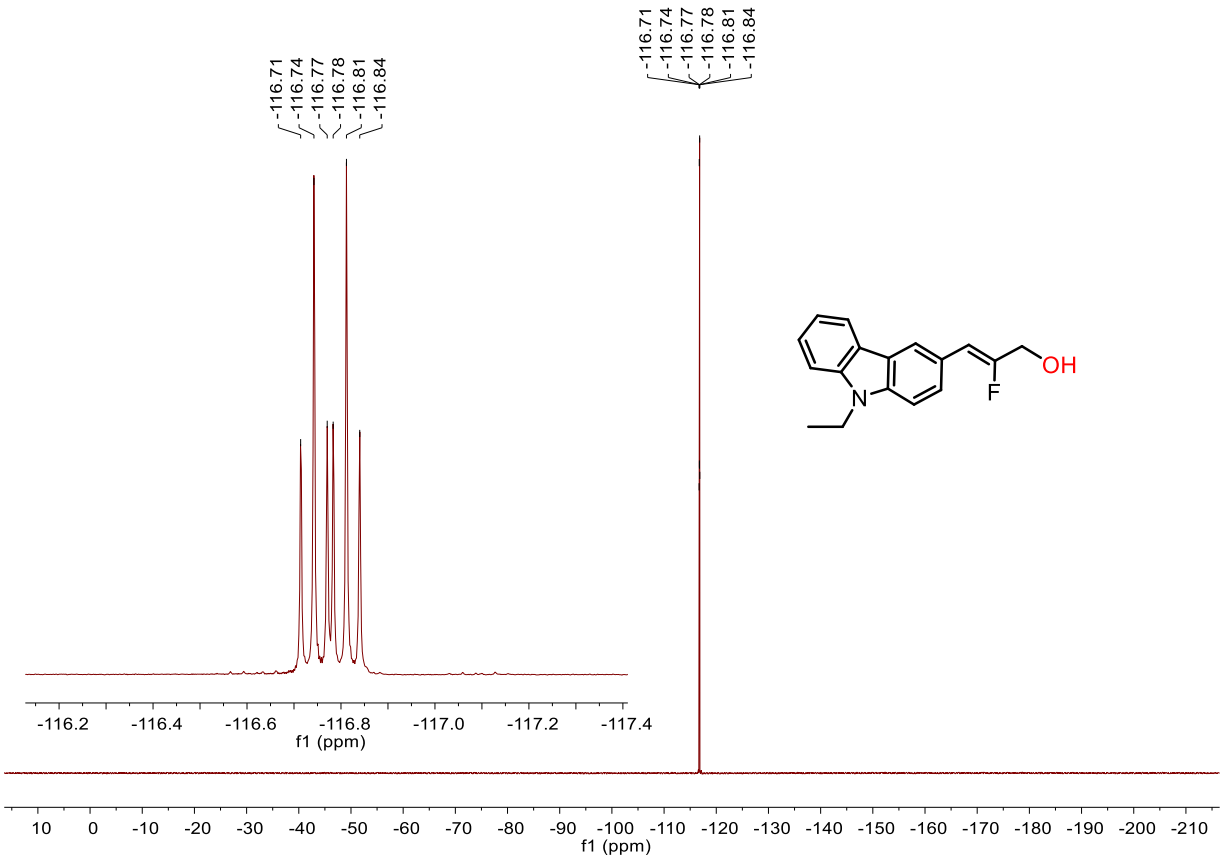
^{13}C NMR (product **2x**)



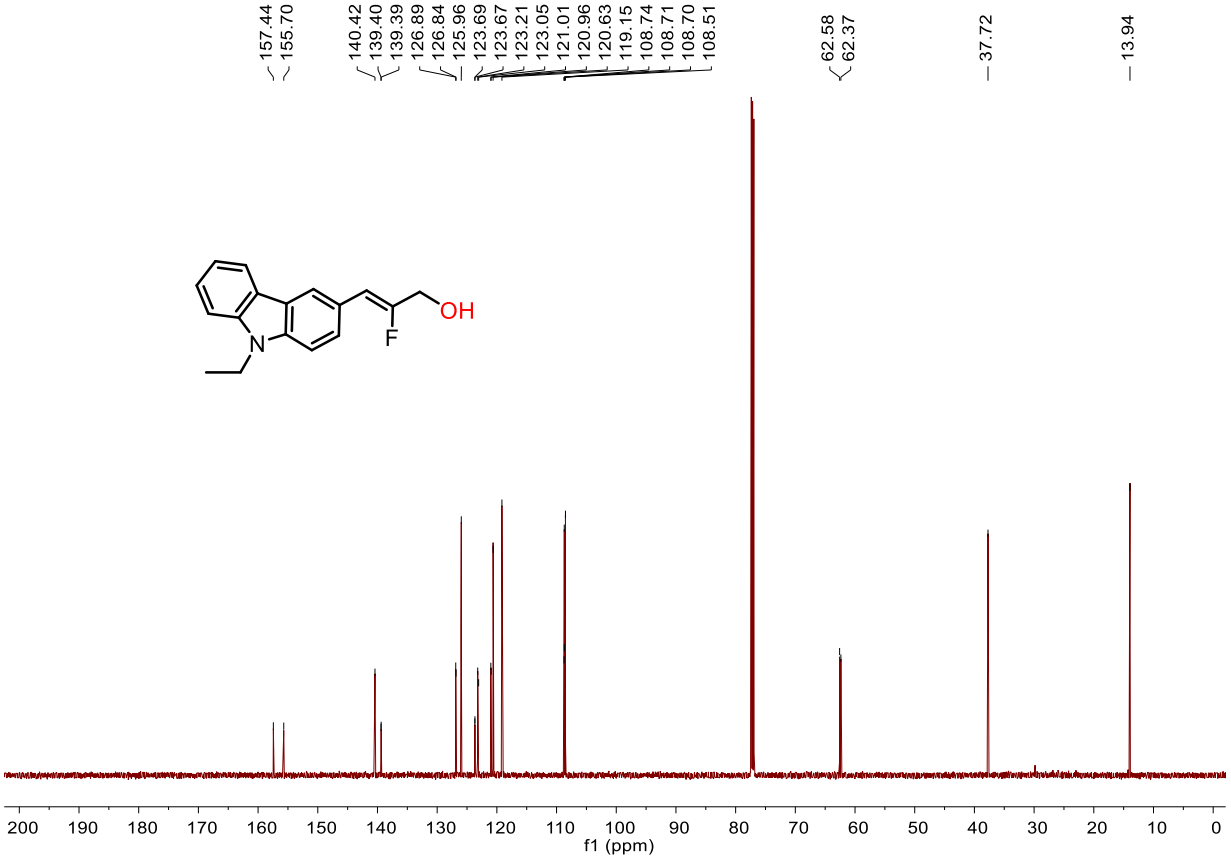
^{1}H NMR (product **2y**)



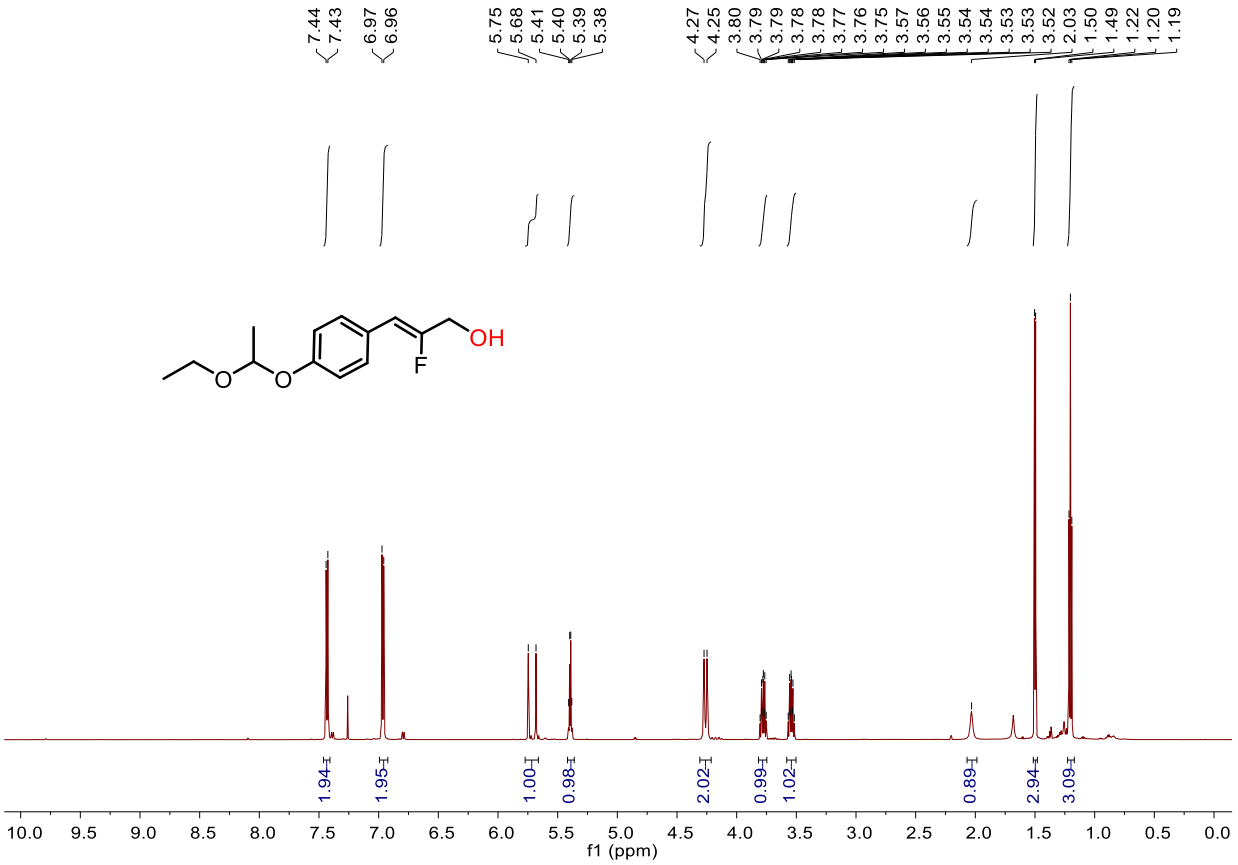
^{19}F NMR (product **2y**)



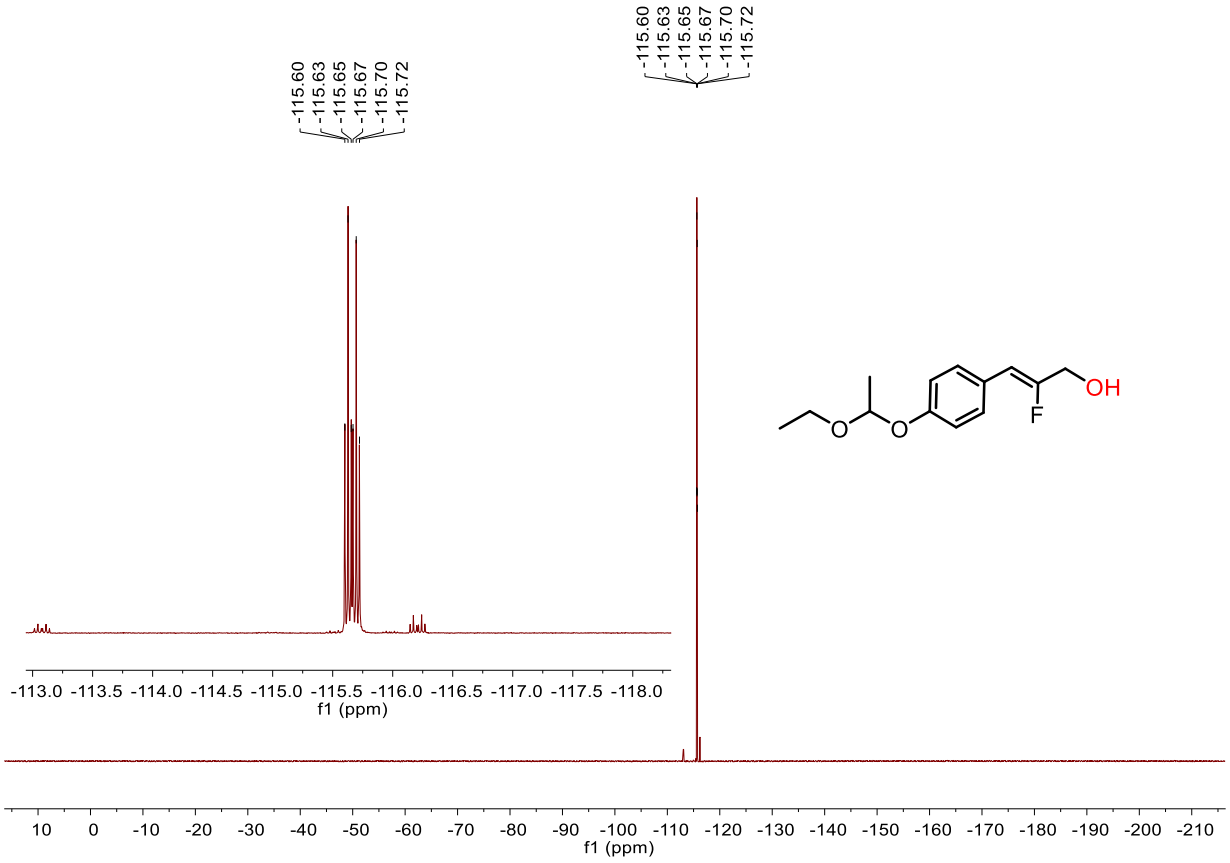
^{13}C NMR (product **2y**)



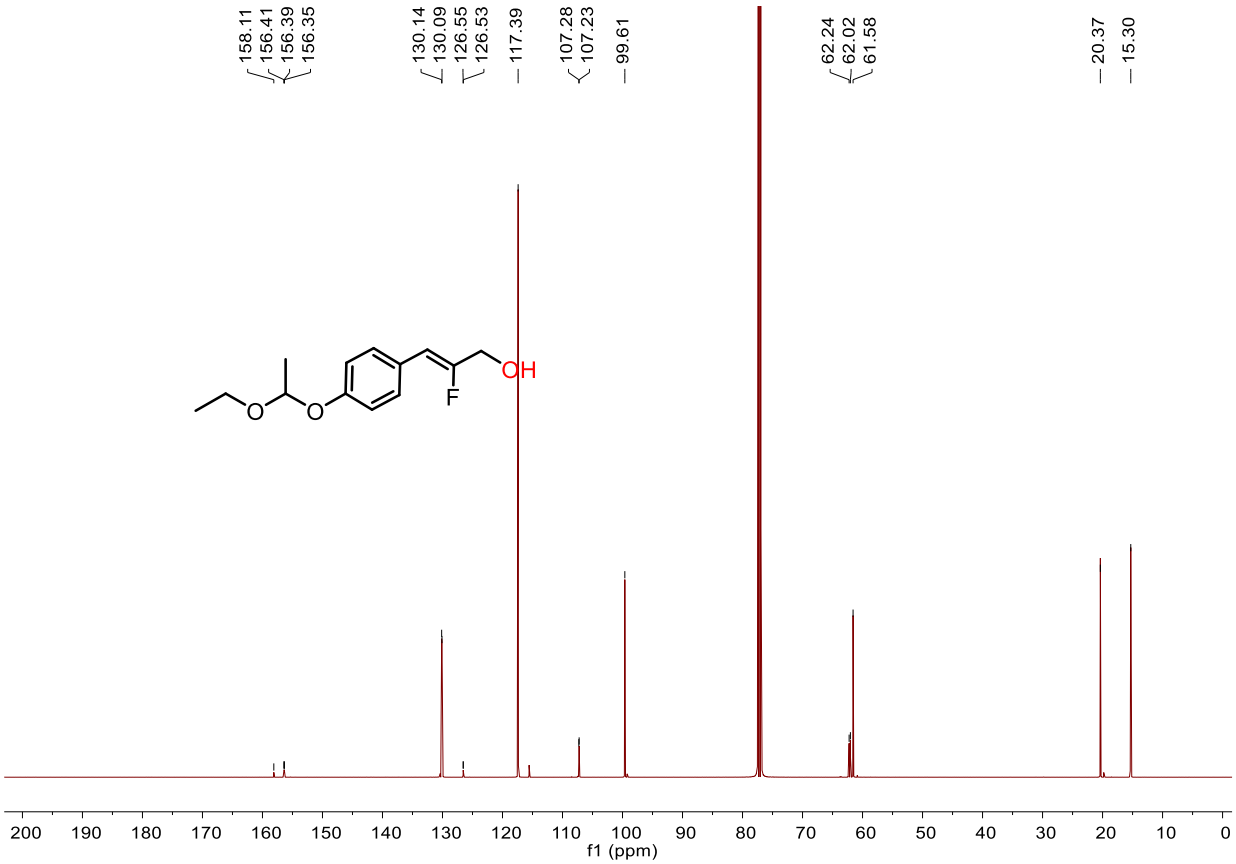
^{1}H NMR (product **2z**)



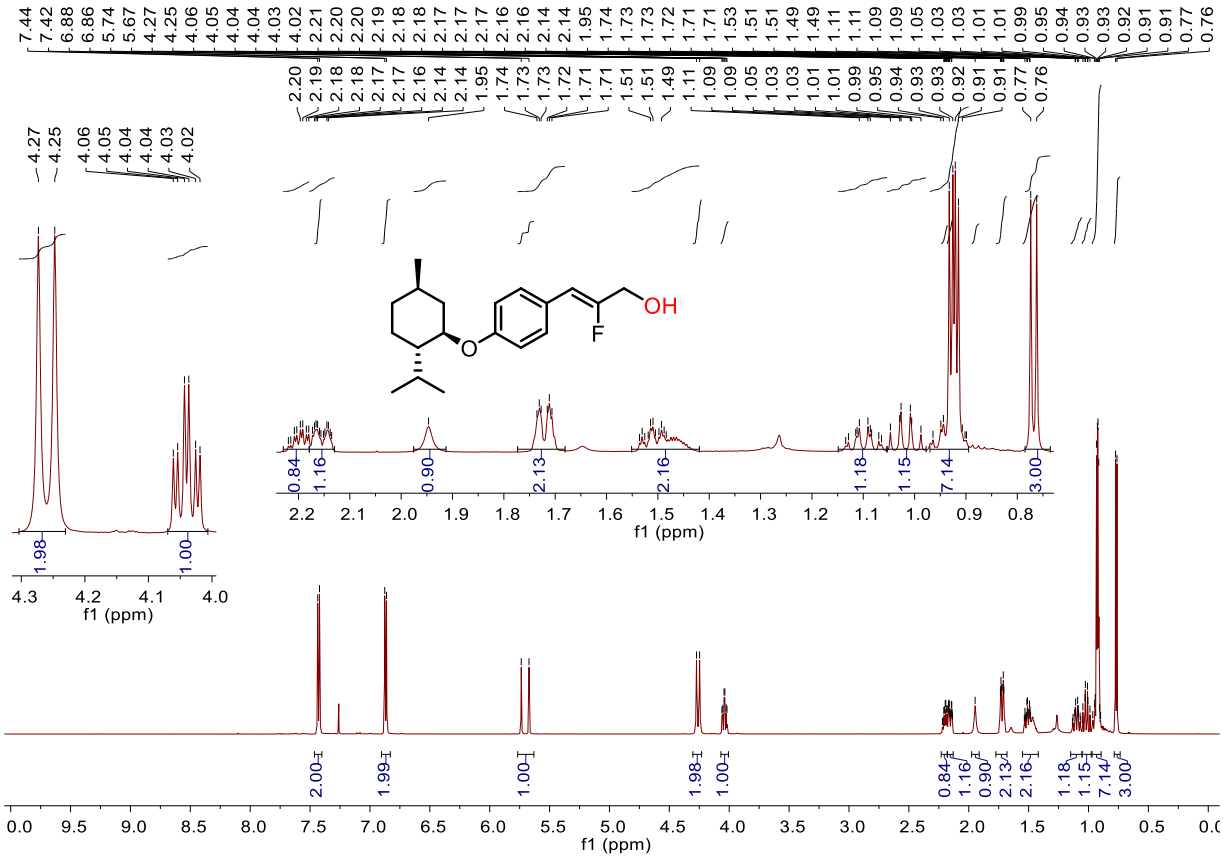
^{19}F NMR (product **2z**)



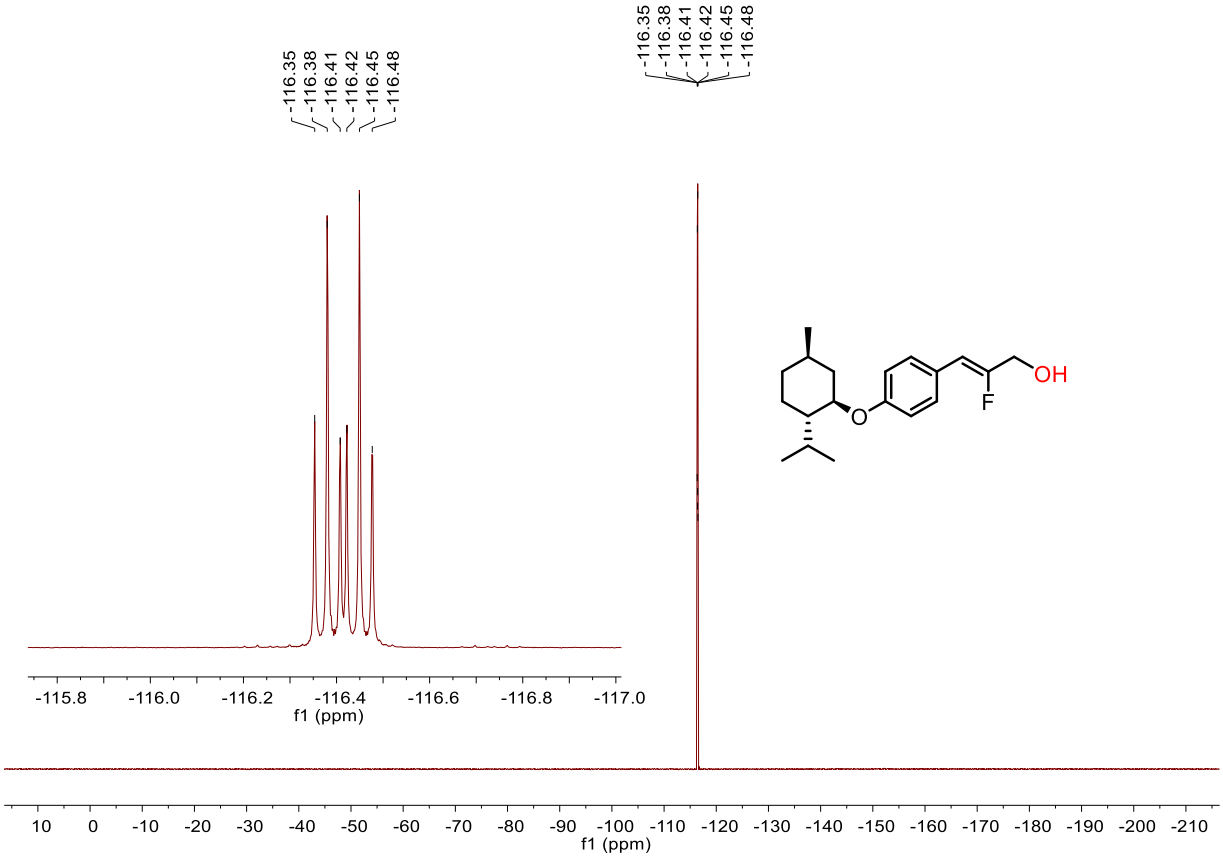
^{13}C NMR (product **2z**)



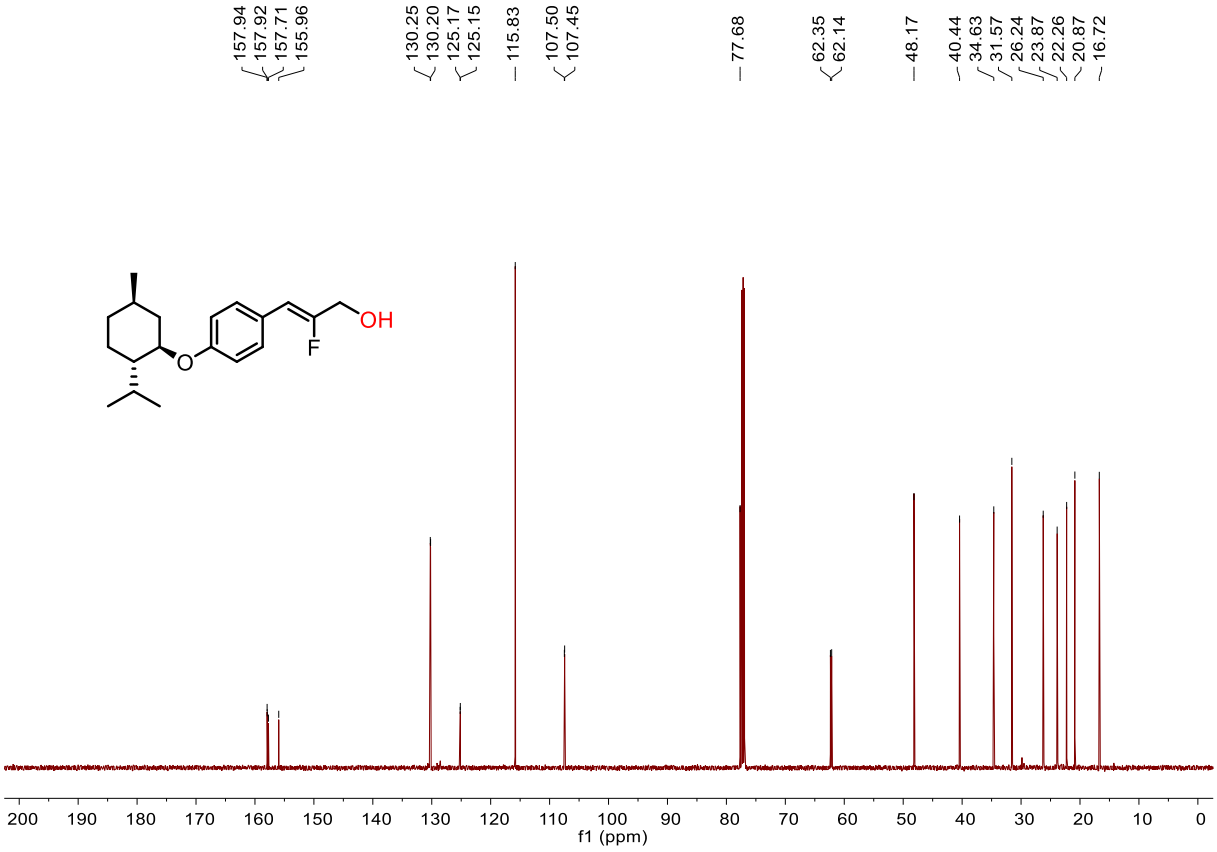
^{1}H NMR (product **2za**)



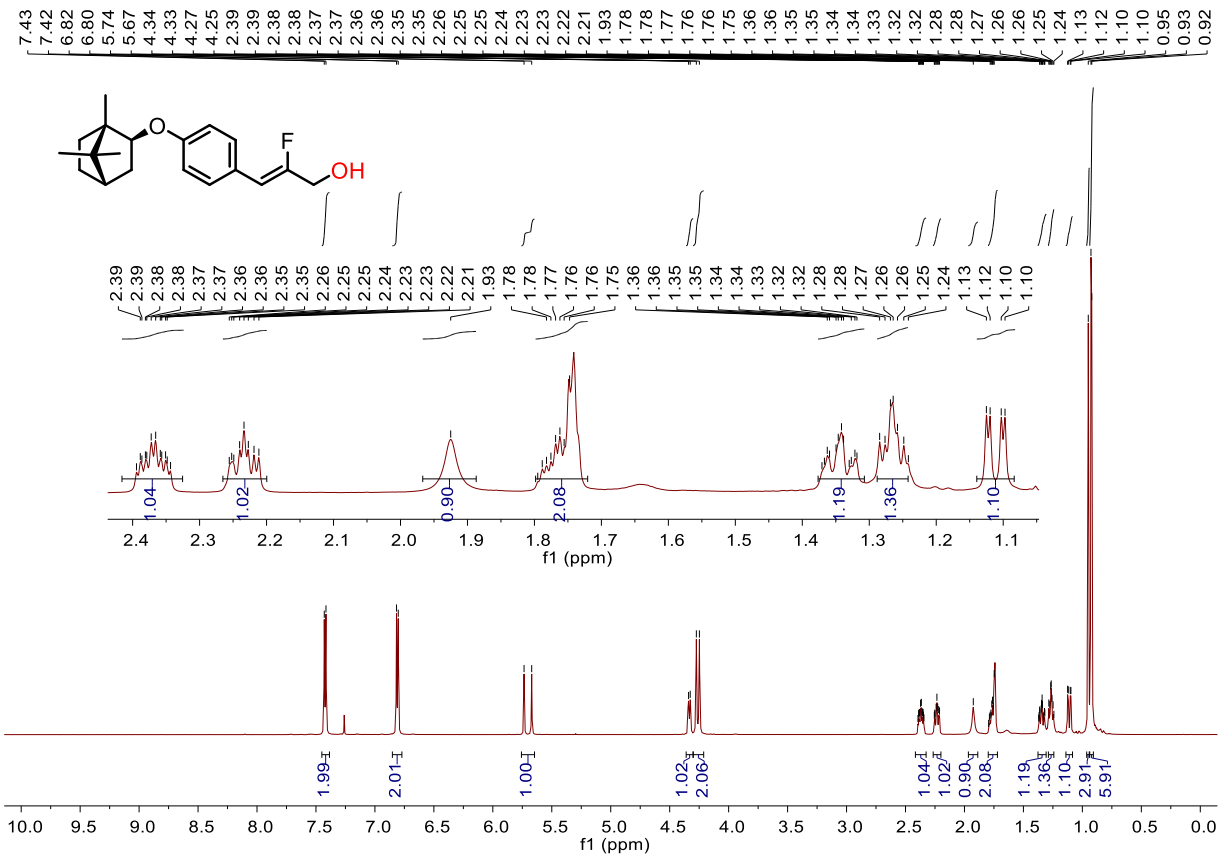
^{19}F NMR (product **2za**)



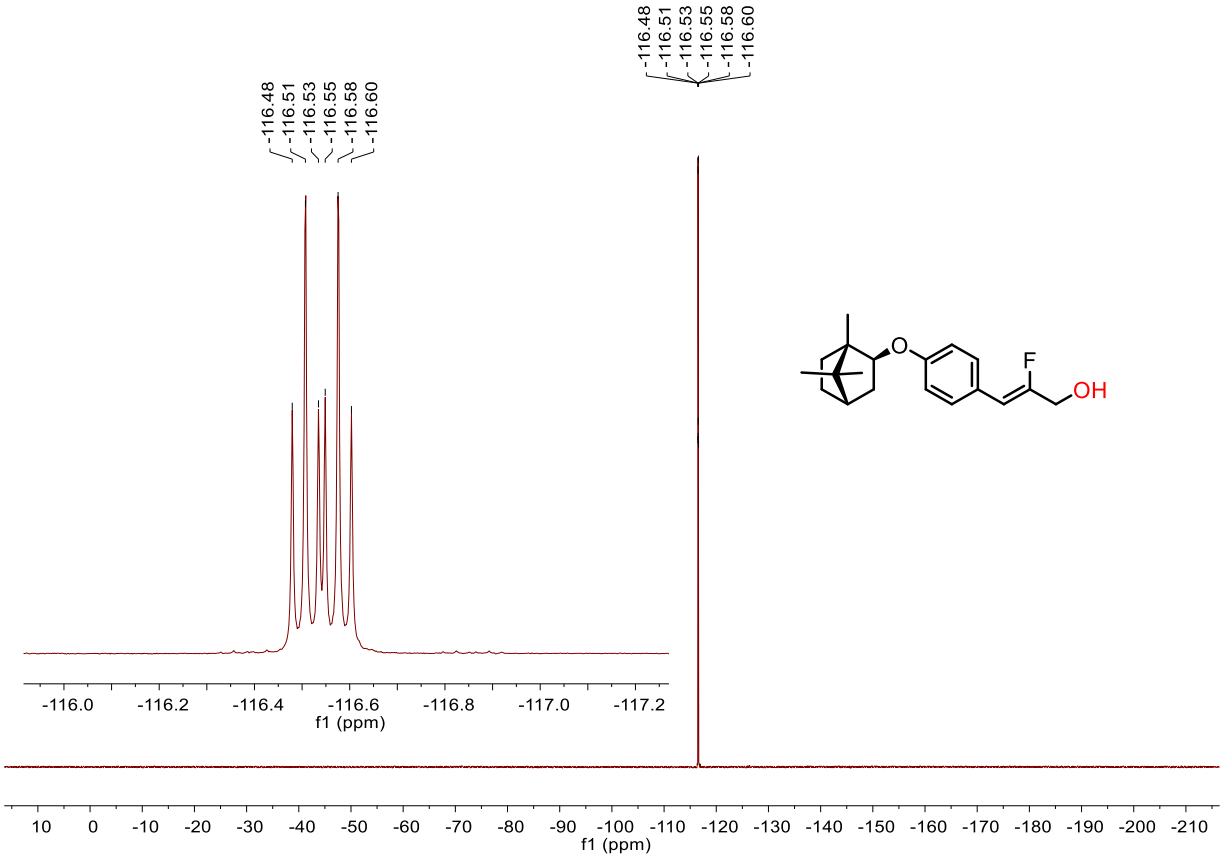
^{13}C NMR (product **2za**)



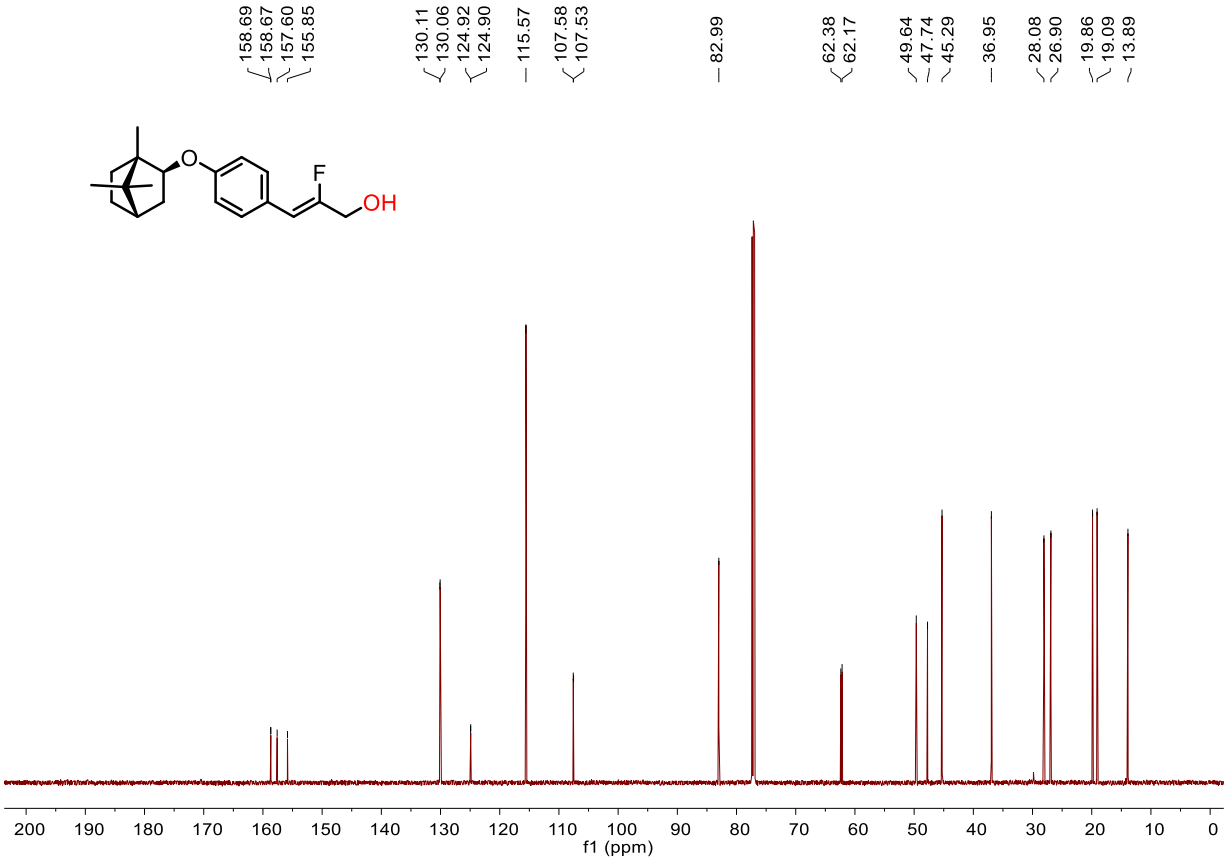
^{1}H NMR (product **2zb**)



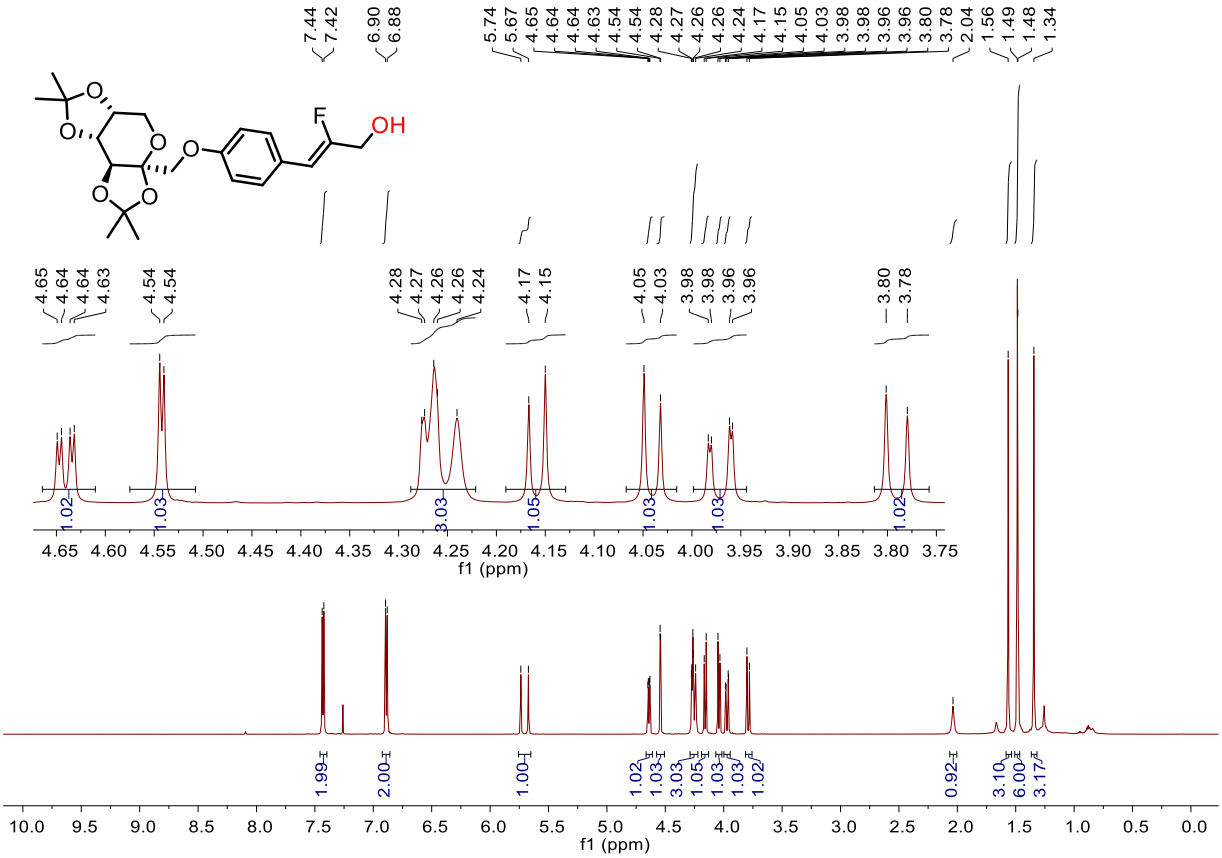
^{19}F NMR (product **2zb**)



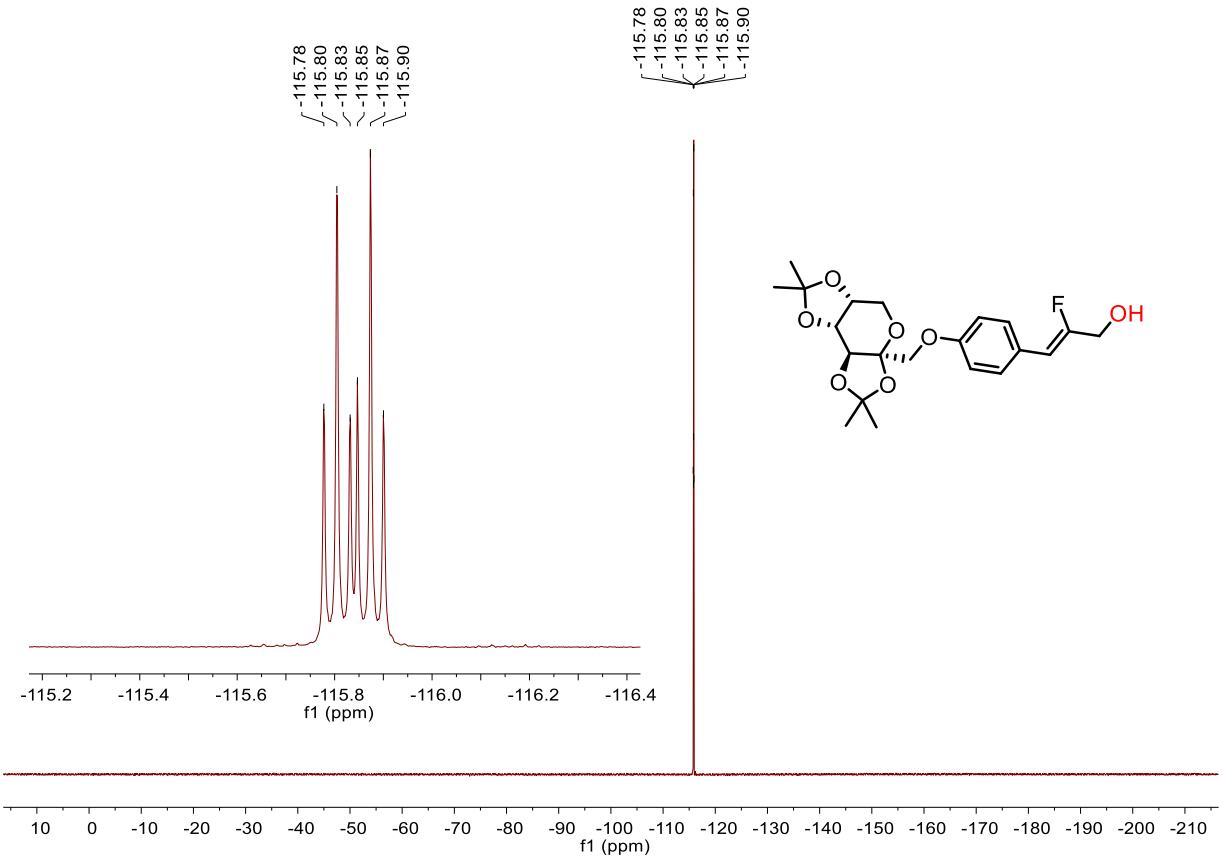
^{13}C NMR (product **2zb**)



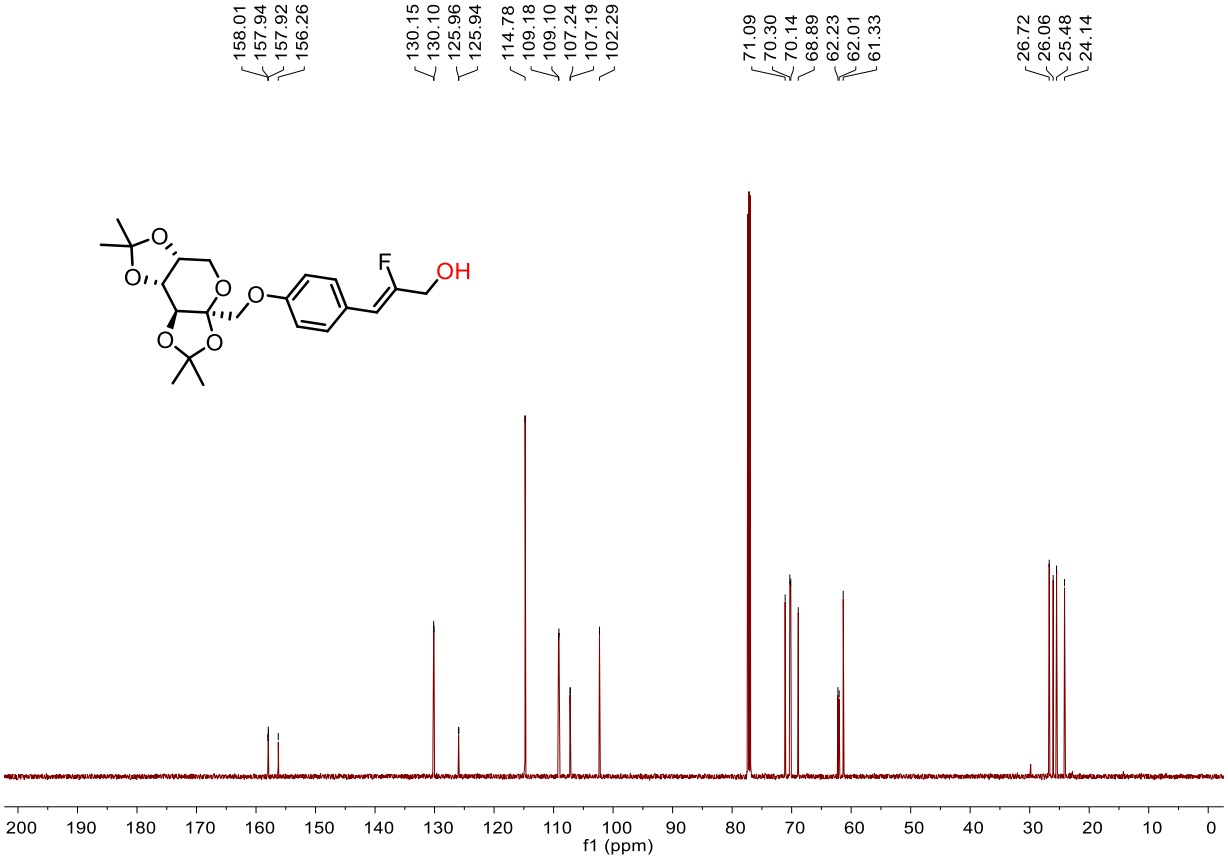
^{1}H NMR (product **2zc**)



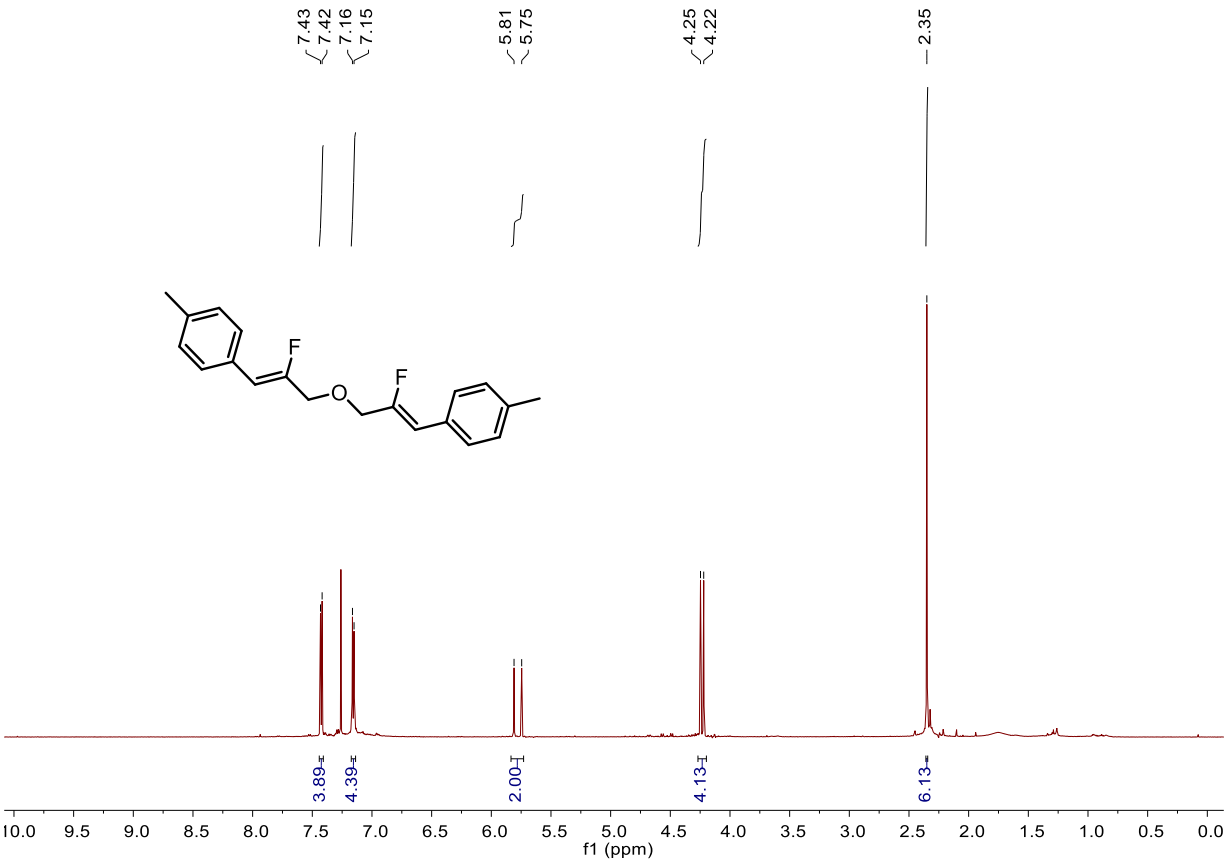
^{19}F NMR (product **2zc**)



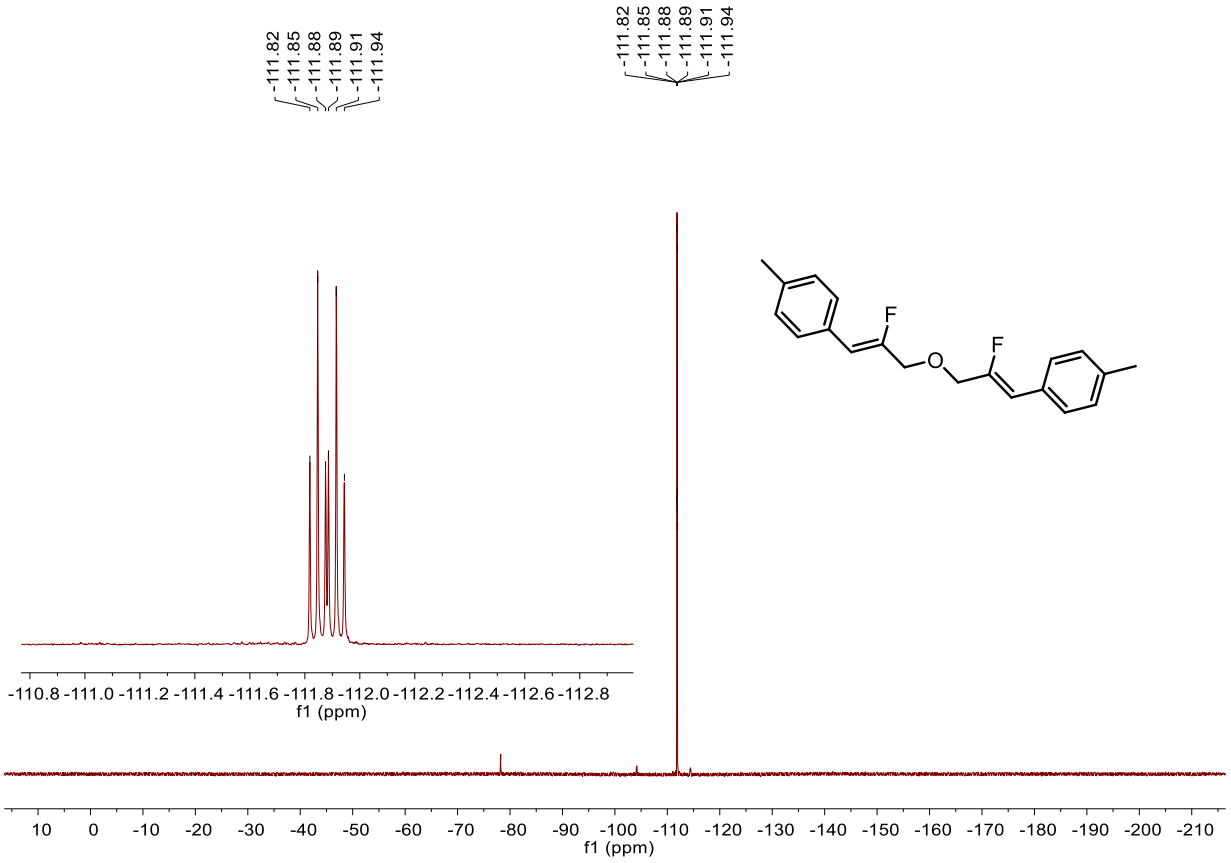
^{13}C NMR (product **2zc)**



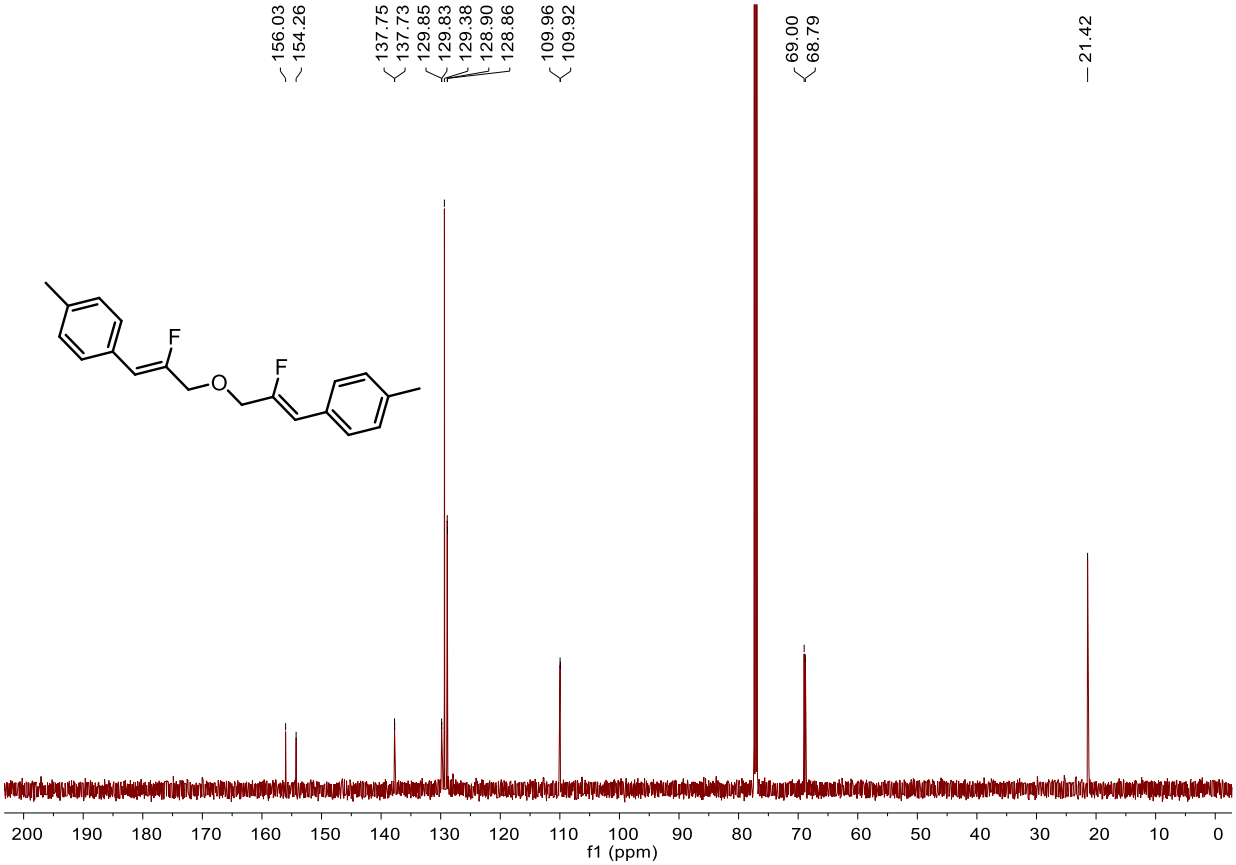
^{1}H NMR (product **3a**)



^{19}F NMR (product **3a**)



^{13}C NMR (product **3a**)



^{1}H NMR (product **5**)